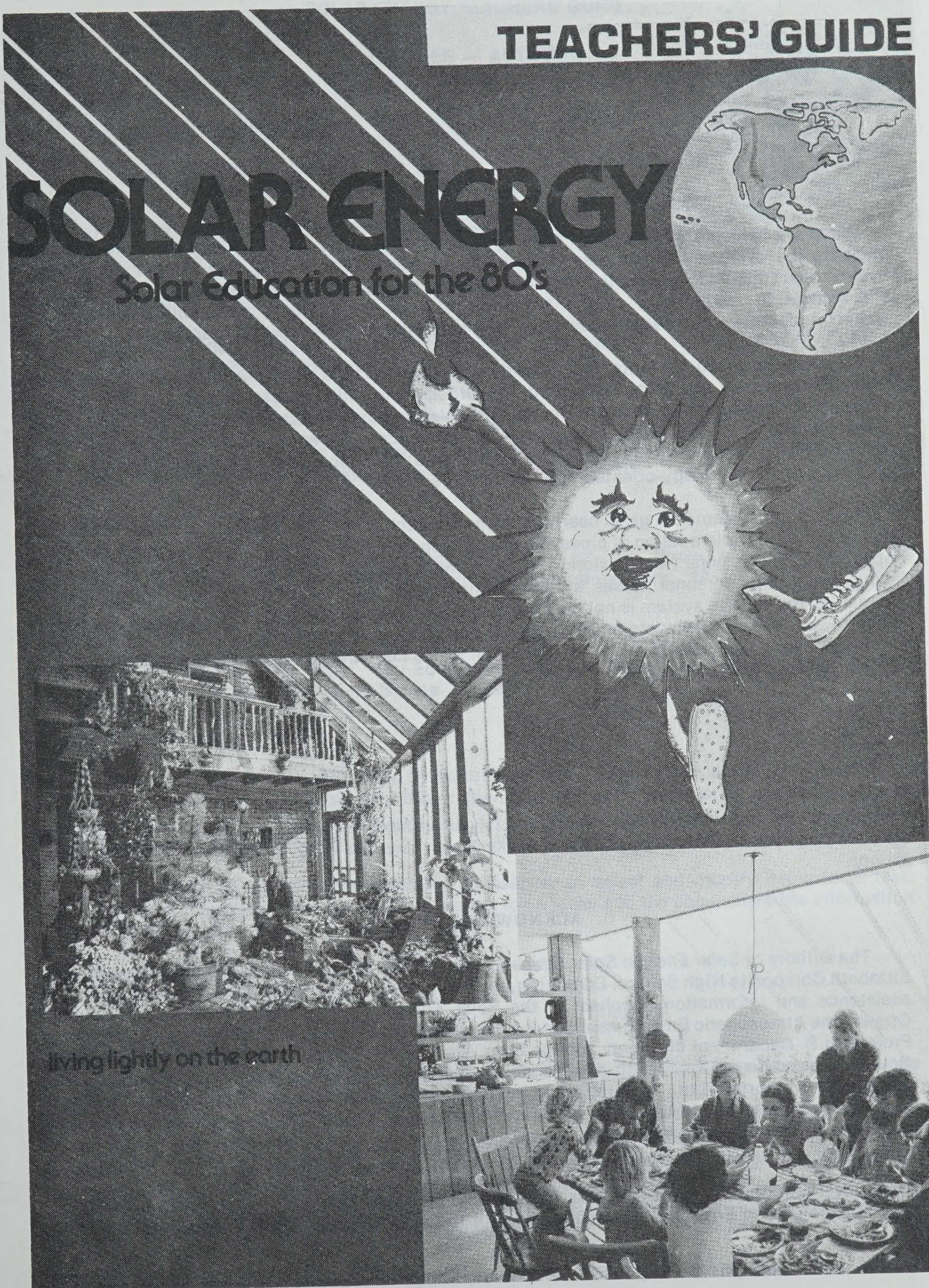
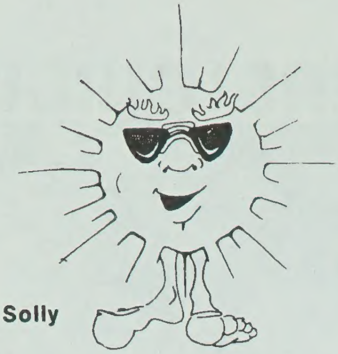

TEACHERS' GUIDE
SOLAR ENERGY
Solar Education for the 80's
living lightly on the earth




## FOREWORD

When we selected solar energy as a special science topic for the classroom, we did not anticipate the overwhelming interest that would be generated. Initially, we sought an applied physics topic suitable for an elective unit. Solar energy seemed appropriate because it could be used as a vehicle to teach many of the principles of heat and light in an applied context. As teacher/students we proceeded to develop and teach the material now in your hands.

To the authors and students, solar energy turned out to be a very special context for learning physics. The physics was being learned but the principles of utilizing solar energy gradually gained emphasis. As we learned more about the topic of solar energy, we came to realize the much larger contexts within which the use of solar energy was embedded. We encountered and engaged in the debate over active solar systems versus passive systems. This debate led us to the realization of the dominance of a technology-oriented mindset in our society.

Active solar systems are given nearly all of the research grants, tax breaks and media attention. Most of the public hold a vision of pipes and special apparatus when solar homes are discussed. We hope to change this solar home vision to that of a well insulated home with a majority of windows facing south. Our personal biases at this moment favor passive solar systems. As an energy alternative, the passive system is not only the cost effective solar system (which is usually the major concern), but the passive system also makes it possible "to live lightly on the earth". As a bonus adopting passive solar energy put us in a position which encourages the critical examination of the mindset of society and of ourselves.

F.J.
H.vK.
G.K
J.K.

Notes:
We hope you interact with this book as strenuously as we have in the first two years of its evolution. We encourage you to write in it, change it, make it your own and use it to evolve your thinking and actions.


## ACKNOWLEDGEMENTS

The authors of *Solar Energy: Solar Education for the 80s* are indebted to the students of Queen Elizabeth Composite High School, Edmonton, for their patience and enthusiasm. We appreciate the assistance and information supplied by the Solar Energy Project, National Research Council, Ottawa; the Atmospheric Environment Service, Fisheries and Environment Canada; the Solar Energy Project, U.S. Department of Energy and the Sun, Wind, Energy Research Project, Alberta Research Council. Thanks to the many individuals who expressed an interest in our project, to John LeBel of J.M. LeBel Enterprises Ltd. for supporting our publishing concepts, to KC Conroy for her endless hours of typesetting and layup-design. A special thanks goes to the families of the authors for their patience, support and understanding.

Front cover photographs are a New Mexico Solar Energy Association photo of a home in Santa Fe, New Mexico and an Environment Canada photo of the ARK at Sprye Point, Prince Edward Island.

**J.M. LeBel Enterprises Ltd., 10372—60 Avenue, Edmonton, Alberta T6H 1G9 (403)-436-8205**

# SOLAR ENERGY TEACHERS' GUIDE


TEACHER — AUTHORS

FRANK JENKINS

GORDON KNIGHT

HANS van KESSEL

JIM KRUGER

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**Acknowledgement**
We would like to thank the anonymous artist whose drawings are shown on Page 16. Anyone knowing the creator, please contact the publisher.


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## Congratulations

Congratulations, you have broken the *"kinds of knowledge for kinds of kids"* supposition prevalent for the last twenty years in secondary science programs. The either/or nature of the assumption that kids who are academically successful should "get" theoretical knowledge and that kids who are not academically successful should "get" applied knowledge needs to be questioned. We have benefitted from the emphasis on theoretical knowledge but a less restricted emphasis is now required.

A restricted classification of kinds of knowledge that is useful is to classify the kinds of knowledge learned in the classroom as *theoretical* and *applied.* For example, theoretical knowledge of thermosiphons would involve the kinetic molecular theory while applied knowledge of thermosiphons would involve their use in passive solar systems in houses.

A similarly restricted classification of ways of knowing inside and outside the classroom is that of theoretical and empirical. There are many curricular and instructional situations in the classroom which illustrate theoretical and empirical ways of knowing. In the curricular situation, knowledge is often presented in the textbook without indicating whether the piece of knowledge has been obtained by a theoretical and/or and empirical way of knowing. For example, theoretically Glauber's salt ($Na_2SO_4 \cdot 10H_2O_{(s)}$) should absorb latent heat and dissolve in its water of hydration at 32°C. This process, in reverse, should release the same quantity of heat. The "should" is a prediction based upon theory (i.e., a theoretical way of knowing).

$$Na_2SO_4 \cdot 10H_2O_{(s)} + \text{heat} \rightleftharpoons Na_2SO_{4(aq)} \qquad t = 32°C$$

Empirically (experimentally, practically, experiencially), this does not work as it "should". Empirically it has been determined that adding borax and peat moss to the Glauber's salt makes the system work "better".

In instructional situations, the commonly employed ways of knowing are theoretical, empirical and memorizing. An empirical way of knowing instructionally often includes laboratory work in a non-applied context (e.g., determine the specific heat capacity of aluminum using calorimeter). The instructional situation is seldom extended to experience outside the classroom (e.g., calculating the heat stored in the thermal mass of the students homes).

In a restricted sense (and all models and theories are restricted cases), the kinds of knowledge and ways of knowing can be represented as below.

| | | Ways of Knowing | |
|---|---|---|---|
| | | Theoretical | Empirical |
| Kinds of Knowledge | Theoretical | | |
| | Applied | | |

Obviously, the distinctions are not to be taken as either/or but the classification system does serve to illustrate that both the students' education and our own education have in the past been narrow. We, as teachers, need to break out of the pattern of teaching what we were taught and how we were taught. We need to expand our kinds of knowledge and our ways of knowing beyond our experiences to create new experiences for ourselves. Teaching <u>Solar Energy - Solar Education for the 80s</u> is such an opportunity.

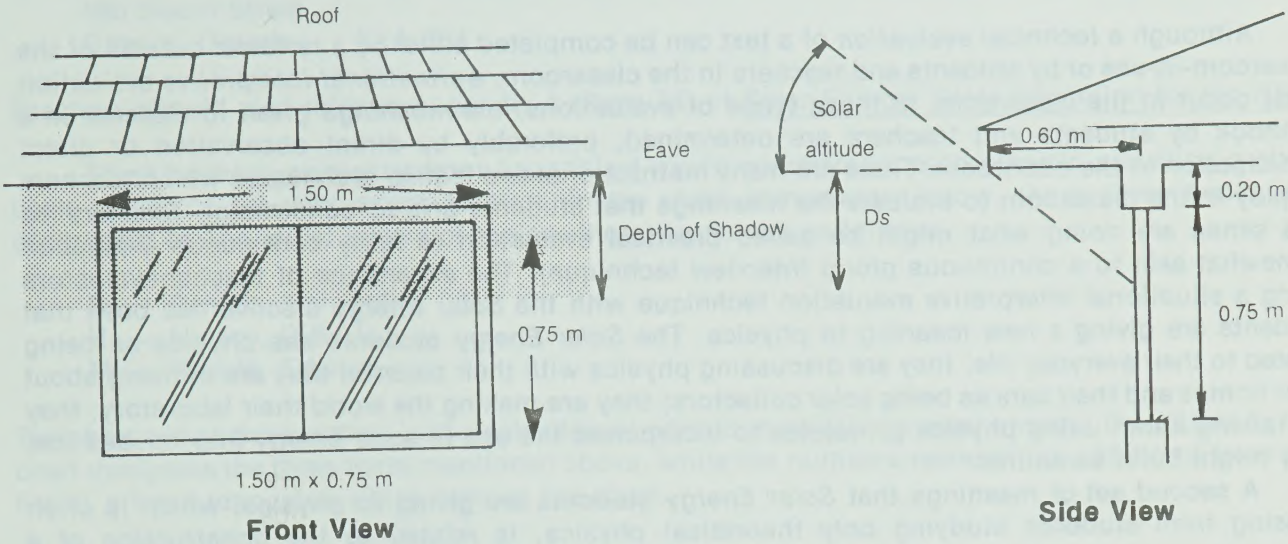
## SOLAR ENERGY—Solar Education for the 80's
## ERATTA and ADDENDUM

**Page 11, Paragraph 5**
Line 1 should read: "At latitudes north of the Tropic of Cancer the sun..."

**Page 17, Figure 19**
Photo is sideways.

**Page 18, Question 3**
Assume an average of 5 people per home.

**Page 27, Question 7**
1. Dimensions of window on diagram below.
2. Noon solar altitude below the diagram.




### SOLAR NOON ALTITUDE CHART
(for Question 7, Page 27)

| Date / Latitude° | June 21 | July 21 May 21 | Aug. 21 April 21 | Sept. 21 March 21 | Oct. 21 Feb. 21 | Nov. 21 Jan. 21 | Dec. 21 |
|---|---|---|---|---|---|---|---|
| 28 | 85.4 | 82.0 | 73.6 | 62.0 | 51.2 | 42.0 | 38.5 |
| 32 | 81.5 | 78.0 | 69.6 | 58.0 | 47.2 | 38.0 | 34.5 |
| 36 | 77.5 | 74.0 | 65.6 | 54.0 | 43.2 | 34.0 | 30.5 |
| 40 | 73.5 | 70.0 | 61.6 | 50.0 | 39.2 | 30.0 | 26.5 |
| 44 | 69.5 | 66.0 | 57.6 | 46.0 | 35.2 | 26.0 | 22.5 |
| 48 | 65.5 | 62.0 | 53.6 | 42.0 | 31.2 | 22.0 | 18.5 |
| 52 | 61.5 | 58.0 | 49.6 | 38.0 | 27.2 | 18.0 | 14.5 |
| 56 | 57.4 | 54.0 | 45.6 | 34.0 | 23.2 | 14.0 | 10.5 |

Note: Government Environment or Weather Service may be able to provide a sun path chart for your exact location.

**Page 38, Question 3**
The question should read: "The illuminated area of a concrete floor measures 3.50 m by 5.00 m ..."

**Page 39**
The symbols *m* and *h* are interchanged.

**Page 49**
In paragraph three, line 4, change the word "radiate" to "conduct".

**Note for Pages 46 and 58**
For safety reasons, plumbing codes require double wall tubes in the heat exchanger when a water-antifreeze mix is used.

**Page 69, Question 3**
Add to question: area of collector is 1.00 $m^2$.

# SOLAR ENERGY - SOLAR EDUCATION FOR THE 80s
# TEXTBOOK EVALUATION

## Technical Evaluation

Elsewhere in this Teachers' Guide is a list of the technical errors in the *Solar Education for the 80s* text discovered by teachers, students and reviewers. There are also a number of typos in the first edition which are not listed but should not affect student understanding of the concepts presented. All of these technical errors plus any others identified in the future will be corrected when the second and subsequent editions are printed.

## Situational - Interpretive Evaluation

Although a *technical evaluation* of a text can be completed either by a reviewer outside of the classroom-in-use or by students and teachers in the classroom, a *situational-interpretive* evaluation must occur in the classroom. In these types of evaluations, the *meanings* given to material in a textbook by students and teachers are determined, preferably by direct observation or direct participation in the classroom. There are many instructional and testing techniques which teachers employ in the classroom to evaluate the meanings that students give to constructs. Teachers in this sense are doing what might be called practical evaluation (a fairly continuous evaluation somewhat akin to a continuous group interview technique). The experience of teacher-evaluators using a situational interpretive evaluation technique with the *Solar Energy* elective has been that students are giving a new meaning to physics. The *Solar Energy* students see physics as being related to their everyday life; they are discussing physics with their parents; they are thinking about their homes and their cars as being solar collectors; they are making the world their laboratory; they are talking about using physics principles to incorporate the use of solar energy into houses that they might build as adults.

A second set of meanings that *Solar Energy* students are giving to physics, which is often missing from students studying *only* theoretical physics, is related to the construction of a discipline. Solar energy in modern society is just now being constructed as a discipline. Students of solar energy are participants in the history of the development of a discipline. Instead of studying the history of a discipline, they are part of the history. Students can discover the effect of society's current way of thinking on the development of scientific knowledge (e.g., the initial emphasis in the solar energy discipline on active high technology systems reflects our society's way of approaching problems).

## Critical Evaluation

While studying solar energy, students can come to see that many of the things we do are never questioned - our actions are not conscious of important considerations (e.g., the type of fireplaces we build, the orientation of houses toward the sun and the air infiltration into homes). Some of the teachers and students even come to notice that in schools we unconsciously match kinds, rather than levels, of knowledge with kinds of kids. *Poor* kids get applied and societal knowledge and *good* kids get theoretical knowledge (pun intended). *Solar Energy - Solar Education for the 80s* is a breakthrough in this regard - applied, societal and theoretical knowledge are integrated.

The "kinds of knowledge for kinds of kids" and the "high technology solar energy components for a high technological society" types of insights are examples of a third type of evaluation called critical reflection. An important question becomes, "Why are we doing this (in this way)?" A surprisingly large number of answers are social and political in nature.

Reviewers, teachers and students need to use all of the above types of evaluation for a complete evaluation of any textbook and most especially one like *Solar Energy - Solar Education for the 80s.* Any textbook evaluation not only determines the value of the textbook but also displays the values of the evaluator. Similarly, the values of the teacher-authors of *Solar Energy* are displayed within the content and format of the book (as the values of any author are displayed within any textbook).

The students of *Solar Energy* have already evaluated the text by 90 per cent of them choosing to buy the book when given the choice of using for "free" or buying the book to keep and continue using. **Perhaps the bookless society predicted for 1984 will not occur after all.**

**An Overview**

The booklet designated immediately below is so valuable to teachers, who are beginning to accumulate resource material for the teaching of solar energy, that it is placed first and by itself.

Conservation and Renewable Energy:
Guide to Sources of Information

This guide can be obtained from:

Communication Branch
Department of Energy, Mines and Resources
580 Booth Street
Ottawa, Ontario K1A 0E4

Teachers should also refer to Appendix 4 (Page 75) of Solar Energy: Solar Education for the 80's.

Three books in particular from Appendix 4 would complement each other in providing a good basic reference set with which to start. In the chart immediately below, these three books are designated by the initial letters of their authors' surnames as follows.

D — Daniels, Farrington
H — Halacy, D.S. Jr.
M — Mazria, Edward

The chart will assist teachers in the selection of printed materials on solar energy. The letters in the chart designate the three texts mentioned above, while the numbers represent the 25 items from the list of printed resources which follows the chart.

| Area of Study Served | Item from Printed Resource Lists |
|---|---|
| Historical and Sociological Background | D, 2, 5, 9 |
| The Physics of Solar Energy | D, 11, 12, 15, 23 |
| Solar Data | D, M, 10, 12, 13, 14, 22 |
| Solar Energy Technology | D, M, 2, 3, 4, 5, 7, 8, 9, 10, 12, 13, 14 15, 16, 17, 19, 21, 22, 23, 24, 25 |
| Economics and Politics of Solar Energy | D, 2, 3, 10, 13, 17, 19, 21 |
| Activities for Students | H, 1, 5, 7, 18, 20, 24 |
| Update (news and recent developments) | 3, 6, 21, 26 |

Please note that most of the items from Page 75 of Solar Energy: Solar Education for the 80's are not included in the above chart but can be evaluated by means of their annotations.

**Teacher Resources - Printed**

1. Barling, John. John Barlings's Solar Fun Book.
Brick House Publishing Company, 1979. 3 Main Street, Andover, Massachusetts, 01810.

*Outlines materials and procedure for construction of 18 solar devices. High school level.*

2. Behrman, Daniel. Solar Energy.
Little Brown and Company, 1976. 34 Beacon Street, Boston, MA, 02106.

*An easy to read, informative, wide ranging account of interviews with leaders in the solar energy field.*

3. Canadian Renewable Energy News.

*A monthly publication giving full, balanced coverage of the renewables field in Canada and around the world. Subscribe to CREN, Box 4869, Station E, Ottawa, Ontario, K1S 5B4.*

4. Carrier, Dean. Solar Houses for a Cold Climate.
John Wiley & Sons Canada Ltd., 1980.

*This is a detailed study of 26 solar heated houses making extensive use of photographs.*

5. Children of the Sun: An Activities Guide on Solar Energy.
Washington State Office of Environmental Education, Shoreline District Offices, N.E. 158th and 20th Avenue N.E., Seattle, WA, 98155.

*This 51 page booklet deals with the technical and sociological aspects of solar energy. It has an extensive annotated bibliography of periodicals.*

6. Current. P.J. Spratt and Association, 212 King Street West, Suite 214, Toronto, Ontario M5H 1K5.

*This is an energy newletter for Ontario teachers [free in Ontario]. Six issues per year.*

7. Davis, W. Douglas. Solar Energy Laboratory Manual.
Crystal Productions, 1979.

*The laboratory activities include suntracking, radiation measurement, trapping solar energy, heat transfer, passive systems and flat plate collectors. Solar Energy Laboratory Manual Teacher's Guide by the same author is also available.*

8. Energy Efficient Housing - A Prairie Approach.
Alberta Energy and Natural Resources and Saskatchewan Mineral Resources, 1980.

*Obtainable from the same source as Item 23 in this list or from Office of Energy Conservation, Saskatchewan Mineral Resources, 1914 Hamilton St. Regina, Saskatchewan S4P 4V4.*

9. Energy Sources for Today: The Renewable Energy Handbook.
Energy Probe, 1978. University of Toronto, 43 Queens Park, Crescent E, Toronto.

*Looks at long term solutions to the energy crisis, discusses social implications and briefly presents many technologies.*

10. Foster, Wm. M. Homeowners Guide to Solar Heating and Cooling.
Tab Books, 1976. Blue Ridge Summit, PA, 17214.

*Step by step analysis of your heating needs and the technology required to meet them by means of solar energy.*

11. Harper, Dorothy. Lets Use the Sun.
Canada Science Series. Multiscience Publications Ltd., 1979. 1253 McGill College, Suite 175, Montreal, Quebec, Canada H3B 2Y5.

*This book presents the basic physical prinicples on which solar technology is based in simple terms with special attention to Canadian needs and problems.*

12. Howell, Yvonne and Bereny, Justin A. Engineer's Guide to Solar Energy.
Solar Energy Information Serivces, 1979. P.O. Box 204, San Mateo, CA, 94401.

*Provides both basic and advanced information for understanding and applying solar heating and cooling technology. Extensive appendices.*

13. Keyes, John H. Consumer Handbook of Solar Energy.
Morgan and Morgan Inc., 1979. 145 Palisade Street, Dobbs Ferry, NY, 10522.

*A comprehensive guide for potential users of solar energy in Canada and U.S.A. Extensive tables, charts and other appendices.*

14. Kreider, Jan F. and Kreith, Frank. Solar Heating and Cooling.
Hemisphere Publishing Corporation, 1977, 19 West 44th Street, New York, NY, 10036.

*A how-to-do-it book that shows how to design systems for buildings.*

15. Meinel, Aden B. and Meinel, Marjorie P. Applied Solar Energy: An Introduction.
Addison-Wesley Publishing Co., 1976, Jacob Way, Reading, MA, 01867.

*A comprehensive, in depth, authoritative discussion of solar energy applications.*

16. McCullagh, J.C. The Solar Greenhouse Book.
Rodale Press, 1978, E. Minor Street, PA, 18049.

*A book on solar greenhouse construction and performance. It is thorough, analytical and authoritative in all important aspects.*

17. Metz, Wm. D. and Hammond, Allen L. Solar Energy in America.
American Association for the Advancement of Science, 1978, 1515 Massachusetts Avenue N.W., Washington, D.C., 20005.

*A review of all the solar energy technologies in the United States.*

18. Norton, Thomas W. Solar Energy Experiments for High School and College Students.
Rodale Press, 1977, E. Minor Street, PA.

*A book of experiments relating to many aspects of solar energy. They use relatively inexpensive equipment and are often described in detail.*

19. Prospects for Solar and Wind Energy Utilization in Alberta.
Alberta Department of Energy and Natural Resources, 1978. 101 pages.

*This and other publications are* **available from Energy** *Conservation Branch, Alberta Energy and Natural Resources, 7th Floor, South Petroleum Plaza, 9915 - 108 Street, Edmonton, Alberta T5K 2C9.*

20. Renewable Energy for Teachers:
The Solar Energy Society of Canada, B.C. Chapter, 1980, 504 Davie Street, Vancouver, B.C., V6B 2G4.

*An extensive list of Canadian resources for energy education along with some suggested activities and topics.*

21. Solar Age
American Section of the International Solar Energy Society, Church Hill, Harrisville, NH, 03450.

*This official monthly publication of the American Section gives information on practical application, research activities and commercial products in the solar energy field.*

22. Solar Energy Handbook
Thomas Nelson and Sons, Ltd., 1979, 81 Curlew Drive, Don Mills, Ontario M3A 2R1.

*A handbook of solar theory and applications with extensive tables and appendices prepared by Ametek Inc.*

23. Solar Energy Matters
Alberta Energy and Natural Resources, 1979.

*Suitable for a wide range of public school students. Written primarily for Alberta teachers and students and may be obtained from the Energy Conservation Branch, Alberta Energy and Natural Resources, 7th Floor, South Petroleum Plaza, 9915 - 108 Street, Edmonton, Alberta T5K 2C9.*

24. Solar Energy Education Project
United States Department of Energy, 1978.

*Contact the Bureau of Science Education of the State Education Department, Albany, New York, 12234 for information on the above project which has produced at least 43 classroom activities suitable for infusion into several science areas. The activities are also appropriate for use in a separate solar energy course.*

25. Turn on the Sun
Ontario Ministry of Energy.

*A booklet pointing out the potential of solar energy and showing how it is currently being used. Obtainable from The Information Office, Ontario Ministry of Energy, 56 Wellesley Street West, Toronto M7A 2B7. Price $2.00.*

26. New Shelter
Rodale's New Shelter, Emmaus, PA 18049 U.S.A.

*A very good magazine which emphasizes lower technology solar applications with a concentration on the homeowner.*

**Teacher Resources - Institutions and Agencies**

Solar and Wind Energy Research Program
Alberta Research Council
4445 Calgary Trail South
Edmonton, Alberta T6H 5R7 (Phone 403-438-1808)

Energy Conservation Branch
Alberta Energy and Natural Resources
7th Floor, South Petroleum Plaza
9915 - 108 Street
Edmonton, Alberta T5K 2C9

Enersave Office, Conservation and Renewable Energy Branch
Energy Mines and Resources
4th Floor, 580 Booth Street
Ottawa, Ontario K1A 0E4

Solar Energy Society of Canada
No. 608 - 870 Cambridge Street
Winnipeg, Manitoba R3M 3H5

*There are over 20 local chapters of the Solar Energy Society in Canada. The addresses of these may be obtained from the above address.*

Communications Branch
Dept. of Energy, Mines and Resources
580 Booth Street
Ottawa, Ontario K1A 0E4

Atmospheric Environment Service
CCAS 4905 Dufferin Street
North York, Ontario M3H 5T4
(a source of Canadian solar radiation data)

American Section of the International Solar Energy Society
P.O. Box 1416
Killeen, Texas, U.S.A. 76541

United States Department of Energy
Public Affairs Division
Washington, D.C. U.S.A.

Solar Energy Applications Laboratory
Colorado State University
Fort Collins, Colorado, U.S.A. 80523

Solar Energy Research Institute (SERI)
1617 Cole Boulevard
Golden, Colorado 80401

*SERI also has a list of sources for programmable calculator and microcomputer solar energy programs.*

Office of Energy Conservation
Saskatchewan Mineral Resources
1914 Hamilton Street
Regina, Saskatchewan S4P 4V4

Ontario Government Publications Service
880 Bay Street, 5th Floor
Toronto, Ontario M5S 1N8

*Use the space below to add the addresses of local institutes and agencies.*

## Audio-Visual Resources - Films and Slides

The use of A-V materials to learn solar energy concepts is essential, particularly to view actual installations. The more recent the film, the greater the emphasis on passive solar energy. Show films outside of class time if necessary. The page numbers in the margin suggest an appropriate location (page number) in the unit for the A-V materials listed. Check local media centres before dealing directly with a film distributor.

*Use these pages to keep track of your evaluations and your order dates.*

1 Energy: A Matter of Choices — 22 min, color, 1973 (with teachers' guide)

This film attempts to explain the "energy crisis" by surveying the attitudes and technological forces that are the bases for our patterns of energy consumption. The film discusses several alternatives, including nuclear, geothermal and solar energy and stresses the need for energy conservation and changes in our attitude and lifestyle.

1 Energy: Problems and the Future — 23 min, color

This National Geographic Society film emphasizes that energy is simply the "power" locked up in nature and that we need to know how to use more than just fossil fuels. The film discusses solar, natural steam, geothermal, tidal, ocean thermal, hydrogen, garbage and wind as sources of energy.

1 Energy to Burn — 25 min, color

Energy to Burn is a BSCS film that addresses the issue of very quickly using a nonrenewable energy source that has taken millions of years to produce. Indirect use of energy (e.g., to make a record) is traced.

1 Energy Carol — 11 min, color

This film, a Canadian National Film Board (NFB) animated production, is a take-off on "A Christmas Carol". Scrooge owns an electrical utility which operates on the idea that "if we didn't waste we couldn't grow."

1 Sun, Wind and Wood — 25 min, color

This is an NFB film which stresses the use of renewable energy sources. Filmed in Prince Edward Island, the point is made that "it is only a level of awareness in PEI that allows this to happen here".

1 Renewable Energy Resources: Wind, Water and Solar Rays
—22 min + 24 min, 2 part audio-slide kit, 1979

This set of 160 slides is suitable for many secondary or post-secondary courses — a good investment. The title represents the content well. Available from Science and Mankind, Inc., Two Holland Avenue, White Plains, New York 10603.

2-3 Solar Energy — Toward the Sun — 28 min, color

Under the assumption that a single day's supply of solar energy is sufficient for a century, the film proceeds to examine how we are using this energy. Various experiments on solar heating and cooling and industrial applications both in Canada and the United States are examined.

2-5 Our Mister Sun — 60 min, color (in 2 parts)

This film presents information about the sun - size, mass, ancient views, eclipses, sun spots and thermonuclear reactions. The energy from the sun in the form of radiation, is related to photosynthesis and also to man's attempts to use this energy.

Western Audio-Visual Enterprises,
806 North Cole Avenue,
Hollywood, California 90038

2-6 **Energy from the Sun** — 11 min, B&W

After noting the importance of the sun as Earth's major energy source, the film goes on to describe how solar radiant energy is transmitted through space and the part it plays in the water cycle and in photosynthesis. Man's present and possible future uses of solar energy are discussed.

Encyclopedia Britanica Educational Corporation,
425 North Michigan Avenue,
Chicago, Illinois 60611
or 115 Berkeley Street (Visual Education Centre)
Toronto 29, Ontario

6-12 **Solar Radiation I: Sun and Earth** — 18 min, color

This excellent National Science Foundation film presents relevant information on the sun and the earth and discusses the energy balance on Earth - solar energy received versus energy emitted by Earth. The effects of revolution, rotation, tilt and atmosphere on the amount of solar energy received are explained.

**Solar Radiation II: The Earth's Atmosphere** — 20 min, color

This second part of the National Science Foundation series on solar radiation deals primarily with the nature of solar radiation and a detailed discussion of the effects of different atmospheric layers on the incoming radiation. The film also returns to the energy balance of the earth discussed in Part I and compares solar and terrestial radiation spectra. (The weather patterns discussed on Earth may be projected to "weather patterns" within a house.)

Universal Education and Visual Arts,
100 Universal City Plaza,
Universal City, California 91608

20-35 **Passive Solar Energy** — 6 slide sets (20 slides/set), audio cassette available

The New Mexico Solar Energy Association has put together an excellent series of slide sets on passive solar energy. Each set contains 20 slides and comes with a written description of each slide (or a taped presentation) by Dr. J.D. Balcomb.

Set A—Passive Soiar Energy—General:
An introduction to passive uses of solar energy including definitions and pictures of direct gain, thermal storage walls, attached greenhouses, natural convection and roof pond systems.

Set B—Passive Solar Energy—Direct Gain:
Includes eleven different Direct Gain applications in various climates.

Set C—Passive Solar Energy—Solar—Geometry, Shading and Movable Insulation:
This set explores three vital considerations of passive solar design.

Set D—Passive Solar Energy—Thermal Storage Walls:
Includes masonry Trombe walls, Drum walls and Combination water and masonry walls.

Set E—Passive Solar Energy—Attached Greenhouses:
Twelve different applications of both integral and retrofit greenhouses.

Set F—Passive Solar Energy—Convective Loops and Roof Ponds:
Water and Air convective systems, roof ponds in California and New Mexico.

New Mexico Solar Energy Association
P.O. Box 2004
Santa Fe, New Mexico 87501

28-29 **The Insulation Story** — 24 min, color

This Canadian National Film Board film begins by illustrating, with infrared photography, heat losses common to most houses. Heat losses by convection, conduction, radiation and evaporation are explained in terms of a house. The function and installation of insulation, vapor barrier and weather stripping are well illustrated with many examples. Efficiency of fireplaces and furnaces is also briefly discussed.

44-52 **How to Make a Solar Heater** — 20 min, color

This film explains a few simple principles of solar water heaters. Using a simulated student project as an example it shows the step-by-step construction of a low cost liquid collector. Other student projects are briefly mentioned as well as some commercial and future large scale solar projects. British units, instead of SI metric units, are used throughout.

Omega Films Ltd.,
32 Howden Road,
Scarborough, Ontario M1R 3E4

59-63 **Solar Energy: Putting Sunshine in Your Life** — 2 part audio slide kit

The first part traces the planning, construction and use of an active-passive solar greenhouse by a high school science class. Part 2 defines and briefly explains both passive and active solar heating systems and ends with a short presentation on the use of solar cells.

Science and Mankind, Inc.,
Two Holland Avenue,
White Plains, New York 10603

59-72 **The Solar Generation** — 20 min, color

This film outlines, with many good examples, the historical, present and future uses of solar energy. Passive and active collection, thermal and latent heat storage, solar cells as well as solar furnaces are described. This survey, along with the advantages and disadvantages of solar energy use, makes this film a good overview of the solar energy field.

59-72 **Solar Frontiers** — 25 min, color

Solar Frontiers is an NFB film which shows four Canadian solar homes combining passive and active systems. The owners of the homes describe how the solar systems work. The noneconomic values of solar and the idea of "technology in balance with nature" are presented.

**Other Sources of Slides and Filmstrips on Solar Energy**

Crystal Productions,
107 Pacific Avenue,
Aspen, Colorado 81611

Educational Materials and Equipment Company
46 Lafayette Avenue,
New Rochelle, New York 10801

**Laboratory Equipment and Materials**

The materials listed below are based on a class size of 32 students. The quantities suggested below are sufficient if students work in groups of 4. These are only the materials for the labs and demos in the book. Other suggested materials are listed elsewhere.

| Quantity | Item |
|---|---|
| 2 — | radiometers |
| 8 — | stroboscopes (hand type satisfactory) |
| 8 — | stopwatches |
| 8 — | convection loops |
| 48 — | thermometers (-10° to 110°) |
| 1 — | floodlight, 150 W, clear (if Labs 3&4 are done indoors) |
| 1 — | stapler |
| 1 — | beaker (large enough to cover radiometer) |
| 2 — rolls | masking tape |
| 64 — sheets | graph paper |
| 48 — pieces | sheet styrofoam (20 cm x 20 cm) |
| 8 — | heat sources (bunsen burners or substitutes) |
| 8 — | dropping bottles of food coloring |
| 1 — sheet | black plastic or paper (to place under radiometer) |
| 1 — | small can flat-black paint |
| 1 — | can of paint (color other than black) |
| 4 L — | ready mix concrete |
| 4 L — | sand |
| 4 L — | small stones (1 to 2 cm in diameter) |
| 4 L — | anhydrous sodium sulfate (Glauber's salt) |
| 1 — | blocks of wood (384 $cm^3$ each) |
| 5 — | 2 L milk cartons |
| 4 — | tin cans (384 mL soup cans are satisfactory) |
| 24 — | can lids or ends (from 1 L juice cans) |
| 6 L — | water |
| 8 — pair | thermal (asbestos) gloves |
| 2 — | cardboard or styrofoam boxes such that one is approximately 5-10 cm larger than the other in each dimension. (One thick styrofoam box would suffice.) |
| — | fibreglass insulation |
| 1 — | sheet of glass or plastic large enough to cover front of box |
| 1 — | block of wood (for support of tilted box) |
| 1 — | sheet of cardboard to make false floor in box |

Many alternative plans for the laboratory work are possible. Some of these alternatives are suggested below.

1. Smaller student groups may be preferred where the equipment supply and storage space is favorable.
2. Larger student groups may be necessary where economy requires it.
3. Assignment of particular phases of an experiment to suitable groups of students is recommended. For example, Lab 4 should have a long period of preheating of heat storage units and also extension of time for reading slowly declining temperatures. Some students who have free time can be assigned these parts.
4. Modification of apparatus may be desirable. Some schools may find it convenient to use alternative kinds of radiometers, sunshine simulators or convection demonstrators and may devise their own solar ovens to suit their needs.
5. The discovery approach can be further emphasized by modifying prelab activities and extending procedures by adding imaginative investigations. These might involve contrived radiometers, color differences, gain from reflection, effects of absorbing surface tilt, convection in fluids other than water, temperature layering in solar heated water, multiple layers of glazing, radiation concentrators, alternative heat storage materials, effects of insulation and many other things which will come to mind as students work on the labs.
6. The involvement of students in modifying the labs and adding new labs would emphasize their involvement in the "history" of the development of solar energy as a discipline.

## Show and Tell Items

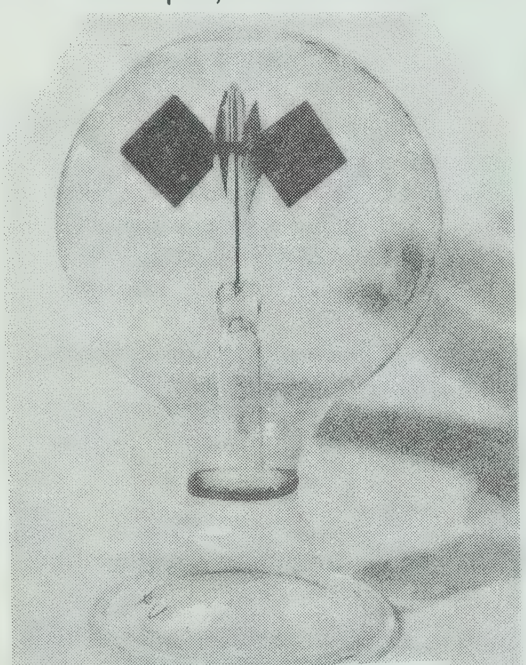
Show-and-tell items in the form of A-V materials, labs, demos, posters, newspaper clippings, books, magazines and display materials are very important for orienting both the teacher and the students. These items should be available in the classroom for immediate use.

For example, models of single and double-wall construction, of air-to-air heat exchangers and of passive solar homes with clerestory windows and/or an integral greenhouse are very useful for spontaneous classroom interactions. These models can be built by the teacher, by building construction students, or as solar energy projects and then purchased by the school.

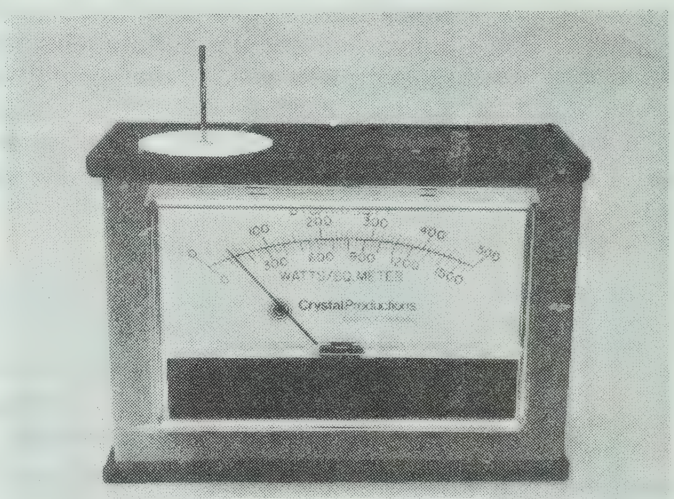
---

## Radiometers for Use in the Solar Unit

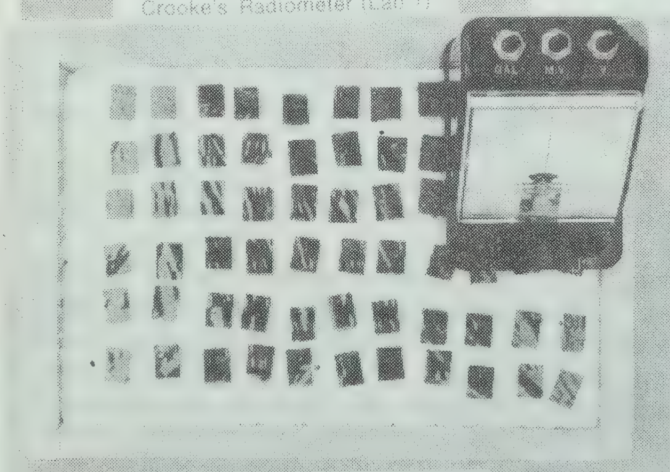
1. The purchase of a photovoltaic solarimeter, although fairly expensive, adds some experience and more meaning to the numbers used to represent the quantity of solar radiation. Students and teachers are more likely to remember a value they measured (e.g. 800 W/m$^2$) than a value from a data table. The photovoltaic solarimeter can remove guessing, can provide absolute rather than relative values, and can be used to calibrate school-made solarimeters.
   One such photovoltaic solarimeter is sold by:
   Crystal Productions
   Box 11480
   Aspen, Colorado 81611



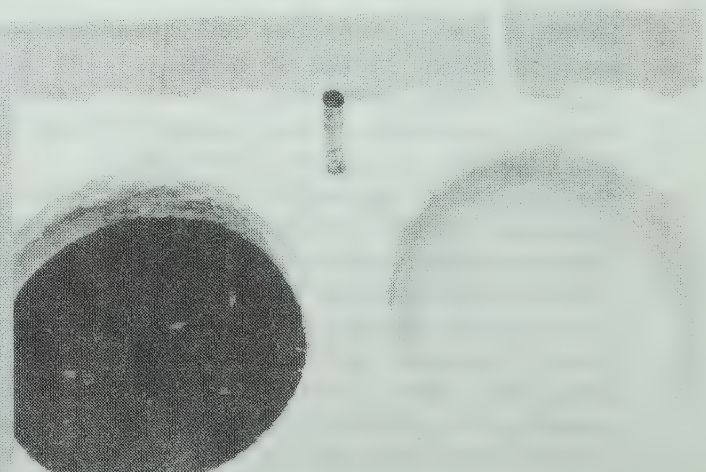
Crooke's Radiometer (Lab 1)




Photovoltaic Solarimeter



Thermoelectric Radiometer



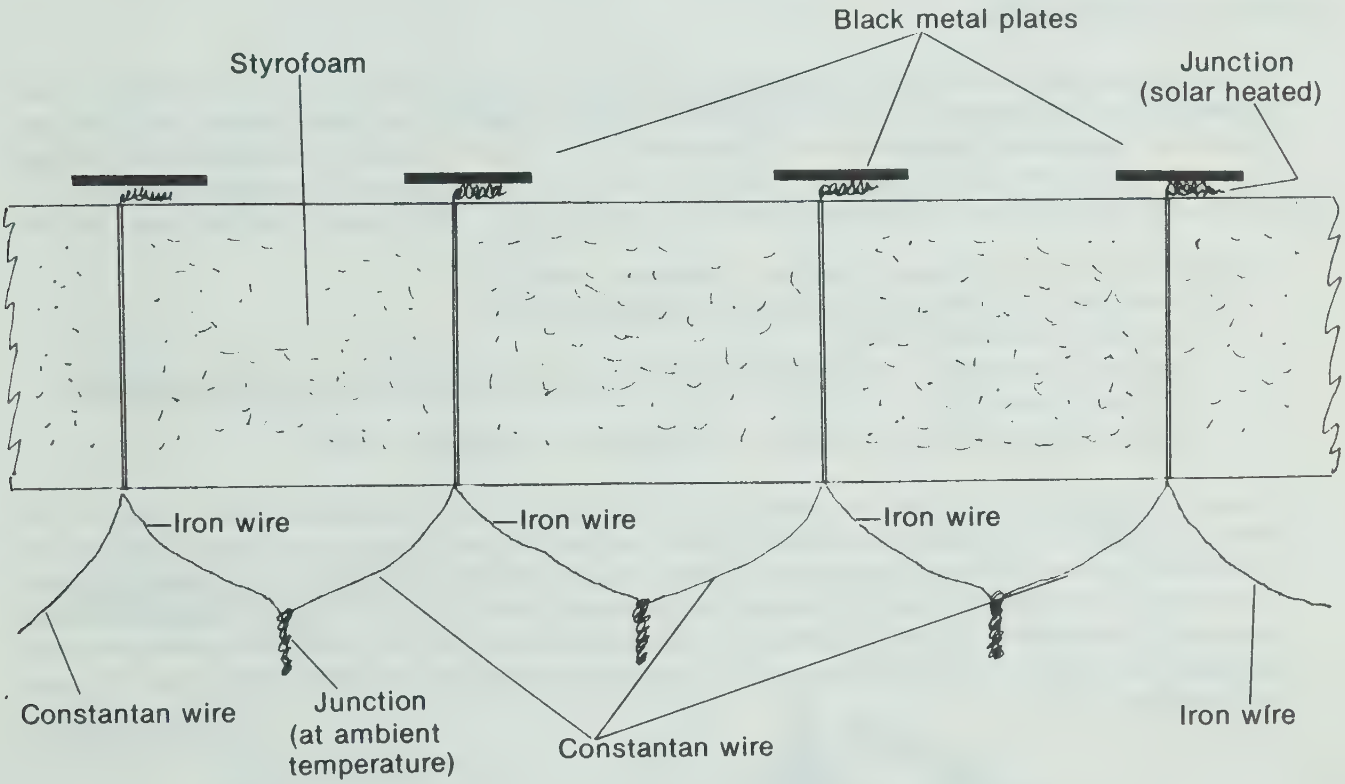
Thermal Radiometer (Lab 3)

## 2. A Simple Radiometer for Thermoelectric Measurement of Solar Radiation

Heating effect is the feature of solar radiation most important to many solar energy applications. Therefore, it is desirable to have an instrument that measures solar heating as directly as possible. One alternative is to construct a thermoelectric (thermopile) instrument as follows.

### Materials

— 5 m thermocouple wire, J type, 20 gauge, nylon insulated. (This type is an iron-constantan pair together in an over-all insulation - price about 80¢/m.)
— 20 cm x 32 cm sheet of styrofoam about 2 cm thick
— 2 $dm^2$ galvanized sheet iron
— flat black paint
— milliammeter (full scale 1 mA) (a microammeter is also satisfactory)
— solder
— tools: tin shears, long-nosed pliers, wire stripper, wire cutter, paint brush, knife, soldering gun.




A Cross-sectional View of
Part of the Radiometer

### Procedure:

(Note: A student could construct this radiometer as his/her solar project.)

1. Paint one side of the sheet metal a flat black. When it is dry, cut it into 60 pieces each about 18 mm square.
2. Cut 60 pieces of thermocouple wire each about 70 mm long and strip both ends of all wires for a distance of about 15 mm.
3. Twist one end of each thermocouple pair together and solder this junction to the unpainted side of an 18 mm square piece of sheet metal from Step 1 above.
4. Cut a sheet of styrofoam 20 cm x 32 cm and punch a grid of 60 holes through it to insert the pairs of wires (6 rows wide and 10 rows long).

5. Insert a pair of thermocouple wires through each hole in the styrofoam so that all their attached pieces of metal are pressed flat against the styrofoam with the black side out (see diagram).
6. On the opposite side of the styrofoam separate the two wires in each pair and solder each iron wire to the constantan wire coming through the neighbouring hole. Continue this procedure so as to make one continuous conductor of all the pairs with only one free constantan end and one free iron end to connect to the terminals of the milliammeter.
7. Place the black surfaces at right angles to solar radiation or artificial light and observe the deflection of the milliammeter needle.
8. Make records of performance and calibration charts as required. (Calibrate this thermoelectric device against a photoelectric solarimeter if available.)
9. Tape a sheet of thin transparent plastic over the side of the instrument with the black metal surfaces in order to minimize the effect of wind.

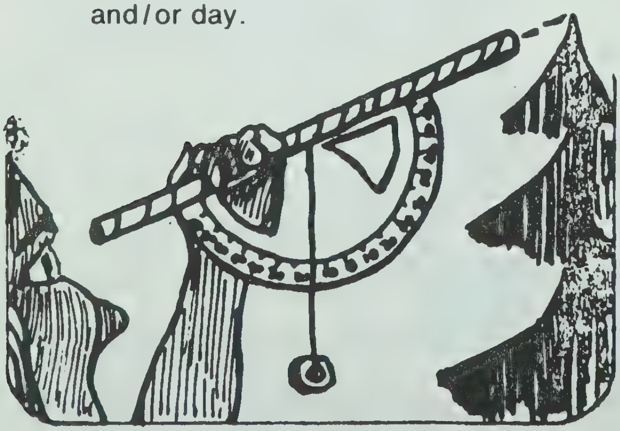
A single iron-constantan junction produces an electric potential difference of about 50 $\mu V/°C$, therefore, 60 junction pairs should give nearly full scale readings on ordinary milliammeters found in most school labs when the instrument is in full sunlight.

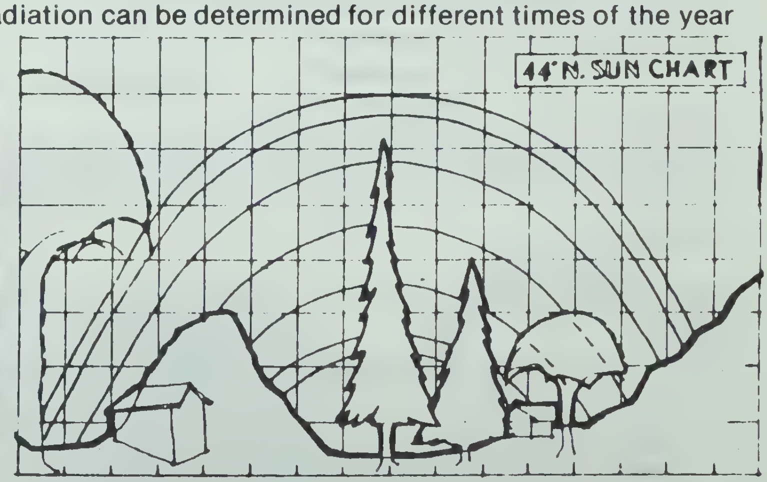
**Additional Laboratory Work**

1. Part of the purpose of the Solar Education for the 80's book is to expand the boundaries of the laboratory to the classroom, to the students' homes, and to the total planet they live on. Additional laboratory work could be a spontaneous or planned demo in the classroom, a heat loss and solar gain calculation of a student's home, or a solar project completed at home.
2. There are several solar energy laboratory manuals available. Three examples are listed below.

   (Addresses are in the Printed Teachers' Resources section.)
   a. Davis, W. Douglas. Solar Energy Laboratory Manual Crystal Productions, 1979
   b. Norton, Thomas W. Solar Energy Experiments for High School and College Students Rodale Press, 1977.
   c. Solar Energy Education Project. US Department of Energy, 1978.

3. A simple solar survey lab can be done using a sun path chart and a plastic straw taped to the straight edge of a protractor. A string tied to the protractor will provide the altitude of surrounding trees, buildings, fences, etc. When the protractor is laid flat, the azimuth of these obstacles can be determined. By plotting on a sun-path chart for your location the altitude and azimuth of obstacles to solar radiation at a particular side (e.g., a south-facing window or a garden), the amount of expected solar radiation can be determined for different times of the year and/or day.



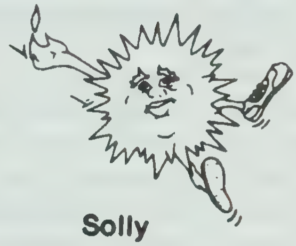



4. A eutectic salt demonstration can be quickly thrown together by mixing about 20 g of anhydrous sodium sulfate with 10 mL of water in a 50 mL beaker. Pass the beaker around the classroom for students to feel the heat released by this reaction. (This can also serve as a good example of the problems associated with eutectic salts by pointing out that theoretically about 25 g of water should be required to form the decahydrate. Empirically this doesn't work for reasons unknown.)

**Evaluation of a Solar Site**

Name______________________________
Block____ ______________________

Shade darkly.
Differenciate between evergreen and deciduous trees.

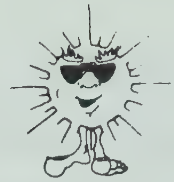


Solly

Put your sun path chart here.

| Overhead Sketch of the Site | Evaluation of the Site |
|---|---|
| Proposed Purposes of the Site | |

Solly



**Purpose:**

1. To construct a solar apparatus (a practical experience).
2. To describe how the constructed solar apparatus works (a theoretical experience).
3. To learn through experience the integral nature of practical and theoretical knowledge in an applied science situation.

**Comments:**

Each student should be encouraged to experience success and/or failure with the above objectives. Parents often assist with the projects; encourage honesty by indicating that your evaluation system can adjust for this situation by weighting theoretical knowledge more heavily than the practical aspects of the projects. Try to get students started early (e.g., in the second week of the unit). Schedule a solar fair outdoors for the last week of the unit and inform the local media! Encourage parents, students and the community to view a display of students' projects.

**Instructions:** **Solar Energy Projects** Class__________________

1. Record your name and other information as soon as possible.
2. Number the project by category and by chronology (i.e., C3 is the third project registered in Category C). (The categories are A-Solar Homes, B-Flat Plate Collectors, C-Solar Greenhouses and Stills, D-Concentrating Collectors, and E-Solar Cells and Radiometers.)
3. See the Solar Energy book for further instructions and suggested projects.
4. Have your teacher check your project plans two weeks or more before the day of the solar fair.
5. Sign-out school equipment on the accompanying sheet.

| Date (198 - ) | Name | Project | Plans | |
|---|---|---|---|---|
| | | | | |

Solly

**School Equipment Required** Class________________

| Name | Equipment | Date Required | Taken (✓) | Returned (✓) |
|---|---|---|---|---|
| | | | | |

# SOLAR ENERGY PROJECT EVALUATION
## EVALUATOR INSTRUCTION SHEET

Solly

| | Relative Weighting<br>Total Possible | Student Mark |
|---|---|---|
| Construction | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| Explanation | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| | 100 | |

Step 1
Initially look at the project in order to determine the extent of work and materials in the context of the particular project.

Step 2
Decide and circle the relative weighting of the total possible Construction/Explanation required for the particular project.

(The relative weighting is a sliding scale which takes into account the fact that some projects involve extensive labor and materials. In such a case a relatively high weighting would be given to the construction part of the evaluation.

Step 3
Evaluate the construction using the specific guidelines given on the evaluation sheet for the particular category.

(Steps 1, 2 and 3 may be done prior to the actual display of the projects by the students.)

Step 4
Evaluate the students' understanding of the principles using the specific guidelines on the category evaluation sheet.

Step 5
Total the marks for construction and explanation.

## SOLAR ENERGY PROJECT EVALUATION
## EVALUATOR INSTRUCTION SHEET

### Category A—Solar Home Models

Project Number

Name:________________________
Title:________________________
Evaluator:______________________

| | Relative Weighting<br>Total Possible | Student Mark |
|---|---|---|
| Construction | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| Explanation | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| | 100 | |

Solly

Construction:

—suitability of materials used to get ideas across
—aesthetic appeal and landscaping
—ease of viewing details of home
—labelling where appropriate
—quality of surfaces and corners (attention to detail)

Explanation:

1. In which direction would the house be oriented? If due south is not possible would SE or SW be chosen.? Explain.
2. Describe how solar energy enters house during the winter.
3. How is the solar energy stored.
4. What features are included to minimize heat loss during the winter season?
5. How is overheating prevented during the summer?
6. Describe and explain relevant landscaping.

# SOLAR ENERGY PROJECT EVALUATION
# EVALUATOR INSTURCTION SHEET

## Category B—Flat Plate Collectors

Name:______________________________

Title:______________________________

Evaluator:__________________________

| |
|---|
| Project Number |

| | Relative Weighting<br>Total Possible | Student Mark |
|---|---|---|
| Construction | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| Explanation | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| | 100 | |

Solly

### Construction:

—"finished" construction details
—suitability and quality of materials used
—proper and effective seals
—sturdiness of the collector
—method and quality of tubing - plate bond
—general plumbing quality
—extent of insulation (collector back)

### Explanation:

1. Explain arrangement and surface of collector panel.
2. Explain purpose of glazing.
3. Why is insulation required? Where?
4. Trace complete operation starting with solar energy reaching collector. (absorption, conduction, thermosyphon)
5. How should the collector be oriented?
6. Explain limitations and compromises of collector design and use.
7. What conclusions (regarding efficiency) can be made from the data collected.

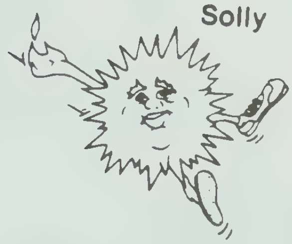
# SOLAR ENERGY PROJECT EVALUATION
# EVALUATOR INSTRUCTION SHEET

## Category C — Solar Greenhouses and Stills

Name:____________________________
Title:____________________________
Evaluator:____________________________

| Project Number |
|---|
| |

| | Relative Weighting<br>Total Possible | Student Mark |
|---|---|---|
| Construction | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| Explanation | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| | 100 | |




### Construction:

—suitability and quality of exterior and interior materials used
—care taken with materials used (check corners, edges, seals)
—provisions for continuous operation of the still (if applicable)
—efficiency of the water collection (no dead water pockets inside the still)

### Explanation:

1. Explain location and orientation.
2. Use "greenhouse principle" to explain operation.
3. Explain choice of material(s) for solar energy absorber (and/or storage)
4. Why does pure water evaporate from the mixture?
5. Why does the water vapor condense?
6. What conditions are necessary for economical large-scale operation?

# SOLAR ENERGY PROJECT EVALUATION
# EVALUATOR INSTRUCTION SHEET

## Category D—Concentrating Collectors and Solar Ovens

Name:______________________________
Title:______________________________
Evaluator:______________________________

| Project Number |
|---|
| |

| | Relative Weighting<br>Total Possible | Student Mark |
|---|---|---|
| Construction | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| Explanation | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| | 100 | |

Solly

Construction.

—suitability and quality of materials used
—sturdiness of construction
—ability to easily obtain proper alignment
—convenient access to and support of sample
—extent of sealing and insulation for ovens
—quality of reflectors (adjustment of reflectors?)

Explanation:

1. Explain location and orientation.
2. Detail operating procedure including results.
3. Explain cooking or heating principle.
4. Explain how location of sample is determined.
5. How can the device be improved?
6. Is this type of device useful or just a novelty? Explain.

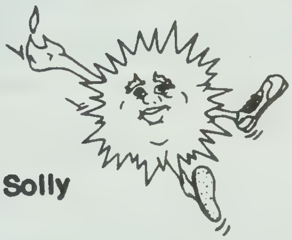
# SOLAR ENERGY PROJECT EVALUATION
# EVALUATOR INSTRUCTION SHEET

## Category E—Solar Cell Projects

Project Number

Name:______________________
Title:______________________
Evaluator:______________________

| | Relative Weighting<br>Total Possible | Student Mark |
|---|---|---|
| Construction | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| Explanation | 20 30 40<br>50 60 70 80 | 5 10 20 30<br>40 50 60 70 80 |
| | 100 | |



**Solly**

Construction:

—support and positioning of the Solar cells
—amount of detail and work involved with electrical circuitry
—quality of materials used
—compactness of unit

Explanation:

1. Explain how number and type of solar cell was chosen.
2. If solar cell charges a battery explain conditions required and principles involved.
3. Can the apparatus operate directly from the solar cells? Why or why not?
4. Explain briefly how electricity is generated by a solar cell.
5. What are the advantages of a solar cell powered apparatus?
6. Explain results, particularly why apparatus does not work if this is the case.

**Notes to the Teacher**

The solar energy field is now being constructed as a discipline. The generalizations accepted today (when this unit was written) are evolving into better or more valid statements and in some cases into more specific relationships. As a result, the suggested answers to the questions may be somewhat indefinite and are based on the generalizations given in the unit. Future editions of Solar Energy: Solar Education for the 80's and the accompanying teachers' guide will evolve with the developing solar energy field. Statements in italics are additional comments or suggestions to the teacher.

**Page 4: Introduction to Solar Energy**

1. According to the present theory, fossil fuels originate from the remains of plants and animals which directly or indirectly depend on plants. Plants grow using sunlight (solar energy) to produce chemical energy through the process of photosynthesis.

*Plants are the bottom rung of the food chain ladder.*

$$\textit{carbon dioxide} + \textit{water} + \textit{light} \xrightarrow{\textit{chlorophyll}} \textit{carbohydrates} + \textit{oxygen}$$

$$6CO_{2[g]} + 6H_2O_{[l]} + 3177.6\ \text{kJ} \longrightarrow \underbrace{C_6H_{12}O_{6[s]}}_{\textit{glucose}} + 6O_{2[g]}$$

2.

| Direct Use | Indirect Use |
|---|---|
| *one step conversions* | *two or more step conversions* |
| light | wood as fuel |
| heating and cooling of houses | food-plant or animal |
| solar cells | wind power |
| distilling sea water | fossil fuels |
| making building materials | hydro power |
| cooking food | |

3. At the present time the direct use of solar energy could not displace all other energy sources. Solar energy is variable, not very concentrated and many uses require long term planning.

4. Mass production almost always reduces the unit cost of a manufactured item. More widespread use and demand should lower the cost of many solar energy applications.

*There are many items not considered in this question. The cost of materials and labor, the competition in a free market and the supply and demand factors could also be discussed.*

5. With the present cost of energy, materials and labor it would not be energy efficient to demolish and rebuild old buildings. However, most buildings can be made more energy efficient with insulation, caulking, weatherstripping, or adding an extra (outside) vapor barrier and wall.

*It is important to consider a total energy use. For example, to add fiberglass insulation may significantly improve an existing building but the production of fiberglass is energy intensive.*

6. Solar energy itself may be free and nonpolluting but to make widespread use of this energy will involve solar energy equipment. This equipment is not free and the industry producing it may pollute the environment.

7. Political:
The committment by governments to alternate energy sources, such as solar energy, can have a great effect on the increased utilization of solar energy. Suitable zoning by-laws, research and development grants and tax allowances are specific examples. The political pressure of large multinational oil corporations may play a significant role in getting subsidized fossil fuel prices rather than solar energy incentives.
Economic:
Government and private investment and supply and demand will be significant economic factors affecting future utilization of solar energy. For example, when house builders realize (like car manufacturers have) that people are interested in energy efficiency, passive solar houses will multiply.
Social:
The orientation of our modern society towards high technological solutions to problems may help advance active systems at the expense of the low technology passive systems. A change away from this type of thinking may take time.
Scientific:
The attitudes of the scientific community regarding sophisticated technology generally reflect those of the society. Research on all aspects of solar energy use is necessary to make solar energy utilization more practical and economic.

**Page 5: Solar Radiation and the Tilt of the Earth**

*In spite of Copernicus, we remain very Earth-centered in our perspective. Solar altitude means the tilt of Earth's surface to the solar beam. Horizontal and vertical are Earth-centered views. The change in effective surface area as a function of tilt can be illustrated by the projection of a file card on an overhead projector or the illuminated area of a flashlight on a chalkboard. The tilt of Earth is more important than the pathlength of the solar beam for determining the solar radiation reaching a horizontal surface on Earth.*

**Page 12: Overview—Earth as a Solar Collector**

1. The intensity of solar radiation striking a horizontal surface depends on the composition of the atmosphere, the pathlength of the radiation through the atmosphere and the tilt of Earth to the sun's rays. Absorption and reflection by natural or man-made materials reduce the intensity of the solar radiation. Increased pathlength also reduces the intensity by increasing the amount of absorption and reflection. Tilt of Earth's surface changes the intensity by changing the effective surface area. A larger tilt produces a more concentrated or intense beam of radiation on Earth's surface.

**Page 5: Energy from the Sun**

*Depending on the background and capabilities of the students the topic of electromagnetic radiation could be done at various levels - from an empirical or operational point of view to a theoretical treament [e.g., $f = c/\lambda$]*

*The observation of the visible spectrum by means of a prism or diffraction grating would be a beneficial class exercise.*

**Page 7: Energy from the Sun**

1. $3.0 \times 10^8$ a $\quad (4\,{}^{1}_{1}H \longrightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}\beta + 2.6 \times 10^9\ \text{kJ})$

2. Since Earth receives a nearly constant intensity of solar radiation, its orbit must be nearly circular. The actual shape is elliptical but with a small eccentricity ("flatness"). Earth is actually closer to the sun during the winter than during the summer.

4. 8.33 min

5. $2.83 \times 10^{23}\ m^2$

6. $1.4\ kW/m^2$

7. $1.8 \times 10^{14}\ kW$

Note:
Units provide the key to the calculations.
The formula is determined by unit dimensional analysis.

2. An increase in carbon dioxide in the atmosphere may result in a heating of the atmosphere and a warmer climate (see Table 2). An increase in the amount of soot may return more radiation back into space and produce a cooler climate.

*Effects of $CO_2$ concentration on the climate is a subject of some controversy and the answer is certainly not simple. Some natural experiments such as major volcanic eruptions seem to verify the effect of soot or particles on the climate.*

3. Much of the "harmful" UV radiation is effectively blocked by absorption in a relatively thin ozone layer.

*Students should be encouraged to search out information about ozone in their school and public libraries. The controversy regarding the fluorocarbon propellents used in aerosol cans would be an interesting sideline.*

4. The time of day (rotation of Earth), season (tilt of Earth) and latitude affect the solar altitude measured at a particular location.

5. June 21: 65°; Dec 21: 18° *Note geometry of this situation.*

6. *The solar altitudes on June 21 and December 21 at a given latitude differ by 47° [2 x 23.5°]. See Figure 13.*

Dec. 21, latitude 53°N : 13°
Dec. 21, latitude 40°N : 26°
The tilt of Earth's surface is the same as the solar altitude.

7. c, d 8. b, f 9. a,e

**Pages 14-16: Lab 1—Measuring Solar Radiation**

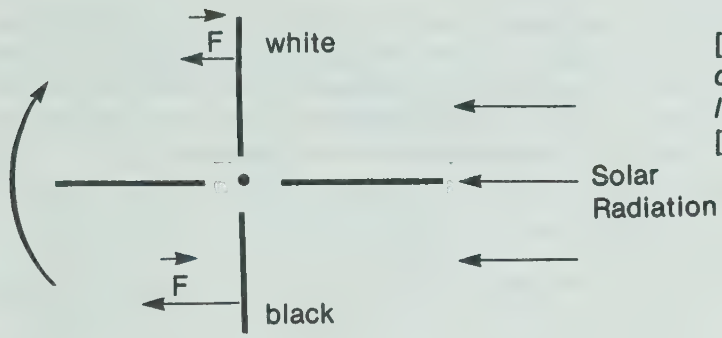
A class of 32, working in pairs, would use the following equipment.

1 - radiometer
16 - stroboscopes
16 - stopwatches
1 - large beaker to cover radiometer
1 - black surface (optional-white surface and aluminum foil)

Unless students have had previous experience with stroboscopes they will require practice before the lab. A record turntable, projector cooling fan, or rotating disk with a variable speed motor could be used for the practice session. A single radial line or a cross-line pattern on a rotating circular piece of cardboard is a good starting point for practice and explanation of the theory.
A determination of solar altitude and azimuth using a simple sun dial could be incorporated into this investigation.
More data can be obtained if several classes pool their results and/or some students volunteer to take measurements outside of class time. This investigation is quite open-ended. Measurements with photovoltaic devices or thermopiles would provide a good comparison and lead nicely into Radiometers on Page 17.

**Prelab Exercise:**

1. Solar radiation is absorbed and converted to heat energy to a much greater extent at the black surface compared to the white surface. The warmer black surface means a greater kinetic energy of the molecules at the surface. Gas molecules colliding with the black surface undergo a greater change in momentum during the collision. Since a greater change in momemtum implies a greater force (assuming the time interval during contact is nearly constant), the vanes will rotate with the white side leading.




(top view)

*[Note to the teacher: The sophistication of students' answers will depend to a large extent on their physics background. [e.g., the study of momentum].*

2. stroboscope: $T_{ave} = \frac{8.2\ s}{10} = 0.82\ s$

   radiometer: $T_{\frac{1}{4}\ turn} = \frac{0.82\ s}{5} = 0.16\ s$

   $T_r = 0.16\ s \times 4 = 0.64\ s$ or $0.66\ s$

   (0.66 s is the answer with no intermediate rounding)

*An alternate approach is that the time for 1/4 revolution of the radiometer was equal to the time for 1/5 of a revolution of the stroboscope. Then find the period and the frequency of the radiometer.*

3. $f_r = \frac{1}{T_r} = \frac{1}{0.64\ s} = 1.6\ Hz$

   *e.g.,* $t_{r_{1/4}} = t_{s_{1/5}} = 8.2\ s / 10 \times 5 = 0.16\ s$

   $T_r = t_{r\,1/4} = 0.16\ s \times 4 = 0.64\ s$

4. The tilt angle (measured from the horizontal) is 90°. Therefore, the vane-collectors are vertical collectors and collect well with lower solar altitudes in the morning, evening and/or winter. The effective solar collecting black surface area is approx. one unit vane area for direct solar radiation. *This lab works very well on snow covered ground.*

**Sample Results: 53.5°N Latitude**

*[Note: If you have other types of radiometers take them outside with you.]*

| Time of Day | Date | Beaker | Weather Conditions | $f_r[H_z]$ |
|---|---|---|---|---|
| 9 15 | May 17 | no | clear | 6.3 |
| 9 45 | May 17 | no | overcast-distinct shadows | 4.5 |
| 9 50 | May 18 | yes | overcast-distinct shadows | 3.3 |
| 10 00 | May 17 | no | overcast-no shadows | 2.7 |
| 13 45 | May 28 | no | clear | 7.3 |
| 14 25 | May 18 | no | clear | 6.7 |
| 14 35 | May 18 | yes | clear | 5.6 |
| 14 30 | May 17 | no | overcast-no shadows | 3.7 |

**Exercise:**

1. The radiometer responds primarily to direct solar radiation. (When sitting on the snow in the winter the indirect solar radiation may be significant.) During very cloudy periods or when shaded the radiometer turns significantly slower.
2. The lower limit on the amount of incident radiation is due to the static friction on the pivot and the internal air resistance.

3. A black sheet was used to minimize reflection from the ground and to stop condensation inside the cover beaker by stopping evaporation of ground moisture.
4. A radiometer is difficult to calibrate because the frequency of rotation is not directly proportional to the incident radiation. Also, measurement errors may be significant. [*A good project for a student might be to draw a calibration curve for a Crooke's radiometer or any home-made radiometer* [*e.g., a thermopile*] *by using a commercial radiometer to provide "absolute" values for solar radiation.*]

*Comments on Questions 5, 6 and 7: Theoretically, the variation of the frequency of the radiometer with time of day and time of year depends on solar altitude and pathlength which are not independent. Low solar altitudes are best for vertical collectors* [*radiometer vanes*] *but result in the longest pathlengths which reduces the intensity of the solar radiation. The restricted theory presented is inadequate for predictions and empirical determinations are necessary.* [*This is an excellent opportunity to talk about restricted theories and theoretical versus empirical ways of knowing.*]

*5 and 6: Variation of the frequency with time of day and year depend largely on individual latitudes and atmospheric conditions.*

7. The frequency should be approximately the same for the same solar altitude. For the same time of day the solar altitude will be less in the winter than in the summer.
8. The glass beaker reduces the frequency due to the absorption and reflection of solar radiation by the glass.
9. For sufficiently large sheets of paper (the diameter of the sheet at least twice the height of the radiometer), the frequency of the radiometer on the white sheet should be greater than the black sheet due to reflection.
10. Because of the opposite colors on each side of a radiometer vane, the radiometer turns in the same direction no matter where the radiation source is. Therefore, a reflecting surface on the back of the beaker should increase the frequency of rotation. [*A diagram may help here.*]

**Page 18: Mean Daily Solar Radiation for a Year**

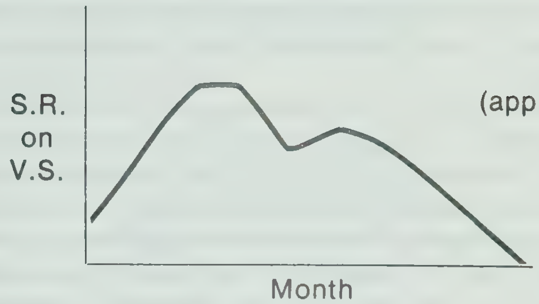
*A particular location can be very approximately identified by its latitude and longitude relative to some distinguishable land or water location. Answers to the questions depend on the specific location.*

1. Energy per year = 100 $m^2$ x mean daily solar radiation x 365 d/a
2. For example, 460 GJ/a : 100 GJ/a is a 4.60:1.00 ratio.
3. *Assume 5 people per home:* $500\,000 \text{ people} \times \frac{1 \text{ home}}{5 \text{ people}} \times \frac{100 \text{ GJ/a}}{\text{home}} \times 1.00 \text{ a} = 1.00 \times 10^7 \text{ GJ}$
4. *Assume your location:* e.g., $12.6 \frac{\text{MJ}}{\text{m}^2.\text{d}} \times 300 \text{ km}^2 \times \frac{1000 \text{ m}}{\text{km}} \times \frac{1000 \text{ m}}{\text{km}} \times \frac{365 \text{ d}}{\text{a}} = 1.38 \times 10^9 \text{ GJ}$
5. e.g., $1.00 \times 10^7$ GJ/$1.38 \times 10^9$ GJ x 100 = 0.725%
   *Assumes an average consumption for your area. How accurate is this?*
6. Isohels, under ideal conditions, should follow the latitude lines.

*The main point to be illustrated by questions 1 to 5 is that the amount of solar energy available is significant. Only very approximate calculations suffice to illustrate this point. For the rest of the book vertical or tilted surfaces will be emphasized, however, the point that should be emphasized here is that the major solar applications are weather and agriculture which are primarily dependent on solar radiation on a horizontal surface. The obvious can often be ignored and this is an example.*

**Page 19: Mean Daily Solar Radiation for Each Month**

1.


*Note that a Northern Hemisphere perspective is taken in this answer and in other places in the book and answer key. Point out restricted perspectives wherever possible.*

2. In the winter months the combination of low solar altitude and long pathlength greatly decreases the intensity of the solar radiation. The high solar altitudes and shorter pathlengths in summer give significantly higher intensities on the horizontal surface.
3. For a south-facing vertical surface (e.g., a window), the solar altitude and pathlength are opposing factors. The solar altitude is best in the winter but the pathlength is at its "worst". A compromise is obtained at the equinoxes - the midpoints between summer and winter.

*The fact that this curve will usually be asymmetrical poses an interesting additional question. Note that climate variations are included in the data used to plot the graphs.*

4. Horizontal data may be useful for agriculture, weather and solar cooling (e.g., roof ponds).
5. Vertical solar data is useful to determine solar heating through windows in buildings.

**Pages 20-24: Passive Collection of Solar Energy**

*Field trips to or slides of local structures can greatly enhance the discussion on this section. Contact local solar energy society for tours, slides or speakers. Student project models from previous classes have also been used effectively to discuss the principles of passive solar design.*

**Page 25: Lab 2—Thermosiphon**

**Materials:**
A class of 32, working in pairs, would use the following equipment.

16 — glass convection loops
16 — heat sources (bunsen burner alcohol lamp or candle)
16 — dropping bottles of concentrated food coloring (dark colors - blue, green, etc.)

Glass convection loops are relatively inexpensive to buy but could also be made from two lengths of glass tubing, a glass or plastic T-joint and pieces of rubber tubing.

**Prelab Exercise:**

As heat energy is gained by a fluid and its temperature rises, the average kinetic energy of the particles in the fluid increases. With very few exceptions, this increased kinetic energy results in a slight increase in the average distance between the particles and therefore the volume increases. The increased volume lowers the density of the fluid.

**Questions:**

1. The density of the water near the heat source decreases and this water is displaced upward in the tube by the cooler (more dense) water from the unheated side. (Note to the teacher: This explanation can be extended to include gravitational force, pressure, buoyancy and the net force involved.)
2. The best location for a passive water collector is near the ground and for the hot water tank is the second floor. Since hot water rises the storage tank must be above the collector for a passive system. [*Alternately the collector and the storage tank can be one and the same thing.*]
3. Solar radiation is converted to heat in an attached greenhouse. The heated air inside the greenhouse enters the house through vents in the top back wall. Vents in the bottom back wall (ideally from the basement) complete the air convection loop.
4. By opening the clerestory windows and a door or window near the ground on the north side of the house, cooler air is drawn in on the north side as the warm air rises out the clerestory windows.
5. Insulating shutters or curtains should be sealed around the window frame to prevent a "reverse" thermosiphon from transferring heat from the room air to the cold window and to the outside by conduction.

**Pages 26-27: Controlling Entry of Solar Energy**

1. During the heating months, the solar azimuth is less than 90° east or west during the day. Therefore, south-facing windows will be in sunlight during the whole day in most locations. [*See figure 12.*]
2. In June the average solar altitude during the day is much greater than in February. The solar radiation is therefore shining more directly on a vertical surface in February than in June.

*A relatively few exceptions in the actual solar radiation data given on the data sheet are probably due to weather conditions unique to those locations.*

3. When comparing collection of solar energy in different locations the factors to be considered are the average daily mean solar radiation (which includes weather and number of hours of sunshine), the average temperatures during the heating season and the cost of alternative energy sources.

4.

| (increase entry during heating season) | (decrease entry during summer) |
|---|---|
| -south-facing and east-facing windows | -roof overhang |
| -window reflectors | -shutters and blinds |
| -passive collectors | -deciduous trees on south, southwest and perhaps southeast |
| -clerestory windows | -dark surfaces outside windows |
| -snow on the ground | -evergreen trees in the north-west |

*Note that some of these items listed also decrease loss of heat* [*e.g., evergreen, shutters and blinds*].

5. 11 $m^2$ to 37 $m^2$ (10% to 33% of total floor area) (See Page 21.)
At northern latitudes (in the northern hemisphere) large window areas lead to net heat losses due to low outdoor temperatures and long hours of darkness during winter months. Large window areas are more practical at southern latitudes.

*This generalization is often recommended by "experts"* [*at the time of writing*]. *Variations due to location, more widespread use of multiple glazings of windows and of insulating shutters may drastically alter this generalization. The important point is that the ratio of window area to floor area is one important consideration in passive solar home design.*

6. *Encourage students to do approximate measurements of their own dwelling or that of relatives or friends. This is a useful exercise to get a feel for the relative areas in a dwelling.*
7. (See Errata Sheet for Edition 1 for information required in this question.)

   depth of shadow = roof overhang x tan(solar altitude)
   net window area = (0.95 m - depth of shadow) x 1.50 m

8. Total window area = 5 x (1.50 m x 0.75 m) = 5.6 $m^2$
   Solar Energy transmitted through the windows = 0.81 x ( Mean Daily Solar Radiation ) x 5.6 $m^2$ x 31 d

*Some explanation may be needed for the glazing transmission coefficient. Note the importance of units in helping to determine the "formula" to be used.*

**Pages 28-29: Minimizing Loss of Solar Energy Collected**

In Edition 1 of Solar Education for the 80's there are no problems provided for calculating the heat lost from a dwelling. Textually the information provided was very up-to-date at the time (i.e., the emphasis in the new solar discipline had quickly changed to low-energy, passive systems and air infiltration was being given the attention it so long deserved), but an exercise to assist student learning is lacking. Teachers should provide some real-world problems for the student to solve. For example:

1. calculate the heat loss through the walls and ceilings of a given house or the student's home.
2. compare the heat loss through an RSI 2.40 and an RSI 6.40 wall.
3. compare the heat loss through a window with the heat loss through a wall.
4. calculate the percent efficiency of a vertical, south-facing window by calculating the heat lost over a 24 h period and the solar gain for the day at various times of the year.

The latter calculation continues the discussion of south-facing windows, window area, the efficiency of windows as collectors and introduces the real need for insulating the window during nondaylight hours. The calculation does not take into account the light energy gained (and saved by not requiring artificial lighting), the view provided by the windows (the human factor), or the potential for growing edible or nonedible plants in the dwelling. A sample calculation is completed below.

Example: Calculate the percent efficiency of a 2.00 m by 5.00 m unobstructed, vertical, south-facing double-glazed, glass window in Edmonton, Alberta during an average day in February. (Assume an average indoor temperature of 20°C.)

Data: glazing transmission coefficient for above = 0.81
mean daily solar radiation for February = 14.1 MJ/($m^2$.d)
RSI for a double glazed window (1.2 cm air) = 0.35 $m^2$.°C/W
(All of the above values come from the data sheets.)
mean daily ambient temperature for February = -10.5°C
(The above value was obtained from the weather office but can be the average high plus average low divided by two obtained from the newspaper for the day before or from a book of such values.)
(A mean daily temperature for each month should be added to the data sheet.)

$$\text{heat lost} = \frac{1}{0.35}\ \frac{\text{W}}{\text{m}^2.°\text{C}} \times 2.00\ \text{m} \times 5.00\ \text{m} \times (20\text{-}10.5)°\text{C}$$
$$\times \frac{3600\ \text{s}}{\text{h}} \times \frac{24\ \text{h}}{\text{d}} \times 1.00\ \text{d} = 75\ \text{MJ}$$

$$\text{solar gain} = 14.1\ \frac{\text{MJ}}{\text{m}^2.\text{d}} \times 2.00\ \text{m} \times 5.00\ \text{m} \times 1.00\ \text{d} \times 0.81 = 114\ \text{MJ}$$

$$\%\ \text{efficiency} = \frac{\text{solar gain - heat lost}}{\text{solar gain}} \times 100 = 34\%$$

By comparison the percent efficiency in January is -3.5% and in March is 55%. (This does not take into account light energy gains through the window or air infiltration losses around the window. Obviously insulating curtains would increase the efficiency substantially.)

Note:

These types of calculations lend themselves very well to programming in a computer.

**Page 30: Increasing Passive Collection and Storage Capacity**

*There is a tendency to consider thermal mass as only the mass in direct sunlight, particularly special structures such as Trombe walls. Thermal mass includes all the mass inside the vapor barrier. For example, double drywalling all walls and ceilings common in some houses would add to the thermal mass of the dwelling. All furniture, carpeting, etc. form part of the thermal mass.*

*Figure 34 could apply to either a passive or active solar home. The area under the house heating load curve represents the total heat required. Solar heat either used during collection or stored for later use can be significant.*

*A discussion of how to increase thermal mass will very quickly show the lack of thought given to this variable when homes are now constructed. For example, all the scrap gypsum board and wood now thrown away could be put inside interior walls, sand could fill [or half fill] interior walls, concrete floors insulated from underneath could be employed, and fireplaces [i.e., the brick] could be located inside the house rather than on an outside wall.*

*Heating by radiation [versus conduction or convection] is very comfortable to human beings. Large thermal mass and, for example, warm exterior walls can increase the percentage of heating by radiation. The radiation flux is very temperature dependent [$h_R \propto T^4$].*

$h_R$ = *emissivity x Stefan-Boltzmann constant x absolute temperature*

$h_R = e\sigma T^4$ (in $W/m^2$)

*emissivity* = *1.00 for a perfect "black body*
= *0.95 for a painted black surface*

*S–B constant* = $5.669 \times 10^{-8}$ $W/(m^2.K^4)$

**Page 31-32 Lab 3—Color of Solar Absorbers**

**Materials:**

A class of 32 students working individually would use the following materials.

- — spray paint (black, green plus other colors)
- 1 — sheet styrofoam (at least 1 cm thick; 1.2 m x 2.4 m size)
- 36 — tin cans (approx. 10 cm diameter-large juice tins)
- 36 — thermometers
- — stopwatches for students without wrist watches

***Note:*** ***Cut the holes in the top sheet by heating the rim of a tin can and then pressing.***

A sheet of styrofoam should make 36 absorber panels. Alternatively, 20 cm by 60 cm panels with three different surfaces could be set up with students working in pairs. Dark colors (other than black) are generally more aesthetically pleasing as interior house colors. There are many colors that could be tried with this in mind. This experiment works best using natural sunlight.

***Try adding some glazing as well and discuss controls in experiments.***

**Prelab Exercise:**

1. *[Note to the teacher: Most students will predict black to be the best followed by progressively lighter colors. Have students make firm predictions on dark colors of greens, blues, browns etc. Some simple color theory could be discussed at this point or following the lab.]*
2. No, a balance will be reached when the rate of heat gain by the absorber panel will equal the rate of heat loss to the surroundings. (An equilibrium much like that for Earth, a house or a solar collector is reached.)

**Sample Results:**

May 10, 25.0°C, 1340 h, clear skies
Temperatures of absorber panels became constant in approximately 10 min. $\Delta t_{max}$ is obtained from the plateau region of each graph.

| | | | | | |
|---|---|---|---|---|---|
| Color: | black, | green, | orange, | grey, | white |
| $\Delta t_{max}$: (°C) | 27 , | 23 , | 18 , | 12 , | 10 |

**Exercise:**

3. Solar radiation is absorbed by the collector surface and converted into heat energy. The slope is an approximate indication of the efficiency of the conversion of radiant to heat energy by each colored surface.
4. As the absorber surface increases in temperature, the rate of heat loss or transfer to the surroundings increases. This heat loss occurs by radiation (primarily from the front), by convection (of air near the warm surfaces) and to a small extent by conduction (through the styrofoam back). When the rate of heat loss becomes equal to the rate of heat gain from the solar radiation, $\Delta t$ becomes constant.

**Page 35: Increasing Passive Collection and Storage Capacity**

1. Two functions of a thermal mass are to absorb heat to prevent overheating and to release heat during cooler periods. Generally a thermal mass should even out temperature highs and lows.
2. Variables which affect the amount of solar energy collected and stored by a thermal mass are location, color, surface area, heat capacity, temperature change, mass or volume and thermal conductivity.
3. Heat from a fireplace is transferred to a room by direct radiation and conduction by the heated masonary material. Convection of room air distributes this heat. A fireplace which draws combustion air from the house sends more heat energy up the chimney and results in a net energy loss (maximum 10% efficiency). (This is an excellent example of the lack of applying the principles of science. An unconditioned accepter of our conventional way of doing things (e.g., a space traveller) would probably assess fireplace as a device to vent the air from a house rather than heat a house.)
   A thermal mass absorbs solar energy and transfers heat by radiation and conduction to the room. Convection of air distributes heat energy in the room.

   *Discuss circulating, "fresh-air" fireplaces, which are now popular, in terms of heat transfer.*

4. As a fluid is heated it becomes less dense and is displaced due to gravity by cooler fluid. A thermosiphon is essentially a convection cell.
5. Trombe walls serve as both collectors and heat storage media providing space heating for a home. They always work when the sun is shining. The main disadvantage is the difficulty of construction, especially in existing homes (i.e., retrofitting).
6. Ave. Max. solar energy $= 0.81 \left( \begin{array}{c} \text{Solar Radiation} \\ \text{for Vertical Surface} \end{array} \right) \times 8.0\ m^2$
7. 

| | Advantage | Disadvantage |
|---|---|---|
| drum walls | -minimizes temp. stratification<br>-easy to construct | -large visual impact |
| culvert storage | -may be more attractive than many drums | -major heating at ceiling due to temp. stratification |

7.

| | Advantage | Disadvantage |
|---|---|---|
| concrete floor | -doesn't block view<br>-heats at floor level<br>-in direct sunlight | -hard under foot<br>-must be massive to prevent high surface temperatures<br>-requires insulation |
| interior brick walls | -aesthetically pleasing<br>-doesn't block view | -extra support may be required<br>-hard to retrofit |
| eutectic salts | -compact heat storage<br>-low temp. operation | -difficult to arrange or build-in<br>-re-cycle problems |

8. Solar energy is free but the equipment, materials and labor to use it efficiently are not free. Pollution may be a factor for solar energy industries. Solar energy is renewable but not always present when it is needed.

*Try to discuss this statement in objective and realistic terms to counteract some of the "hype" in the news media and from irresponsible solar business enthusiasts. Then try to discuss the statement in subjective terms and let everybody's values fall where they may [i.e., the decision "to go solar" or to use fossil fuels or nuclear is very much a value decision as well as an economic decision]. There are political, ethical, economic and social ways of knowing associated with real-life problems such as the energy crisis.*

**Page 37 Solar Heat Storage**

*It may be useful at this point to refer back to Figure 14 on Page 30.*

*More detail or depth could be added by discussing heat storage in terms of changes in kinetic energy [thermal heat storage] or changes in potential energy [latent heat storage].*

*When calculating and discussing quantities of heat, special emphasis should be placed on the significance or meaning of the amount of heat in terms students [and teachers] can relate to. Have students, when possible, look up their utility bills to determine actual energy consumption values.*

*The following approximate values may be useful.*

*Annual per person energy consumption in North America*..................200 GJ
*Thermal energy content of 1 t of coal*..........................................20 GJ
*Thermal energy content of 1 bbl of petroleum*..................................6 GJ
*Thermal energy output of average home furnace running for 12 h*.............1 GJ
*Thermal energy content of 1 $m^3$ of natural gas*..............................40 MJ
*Thermal energy content of 1 L of gasoline*........................................36 MJ
*Minimum daily food supply to maintain human life*..............................8 MJ
*Electrical energy consumed by kettle in 10 min*..................................0.9 MJ

Note the error on the data sheet in Edition 1; 1 kW.h = 3.6 MJ.

**Page 38: Thermal Heat Storage**

1. 0.60 GJ ($6.00)
2. 0.59 GJ ($5.90) ($V = \pi r^2 h$ may have to be given to students.)
3. *In Edition 1 this is a very easy question since the answer is given in the question. This was not intended! Have students cross out the 0.24 m in the question.*

**Page 39-40: Eutectic Salts**

*The compactness of the heat storage of eutectic salts [illustrated by questions on Page 40] is very attractive. Present research and some actual installations point to multiple containers and mixtures including other salts [e.g., borax] and/or peat moss as partial solutions to the problems listed.*

1. 353 MJ
2. 8.4 $m^3$ *-to store the same amount of heat as*
3. 17 $m^3$ *1.00 $m^3$ of Glauber's Salt*

**Pages 41-43: Lab 4—Solar Heat Storage**

<u>Prelab - Solar Oven</u>

2 - cardboard or styrofoam boxes such that one is approximately 5-10 cm larger than the other in each dimension. (One thick styrofoam box would suffice.)
1 - piece of cardboard to serve as a false floor
1 - sheet of glass or clear plastic large enough to cover the front of the larger box
- insulation (fiberglass)
- flat-black spray paint
- support block
1 - roll masking tape
1 - thermometer (-10 to 110°C)

*<u>Notes:</u>*
1. *A school electric oven would suffice.*
2. *Reflectors on the oven would produce a higher oven temperature.*
3. *This would make for a good student project.*

<u>Lab Materials:</u>

4 - small tin cans painted flat-black on the outside (384 mL soup cans are satisfactory)
5 - 2 L milk cartons
6 - thermometers (-10 to 110°)
1 - block of wood painted black (384 $cm^3$)
- sand
- small stones
- thermal gloves
- water
- ready mix concrete
1 - stapler
1 - roll masking tape
1 - watch or clock
2 - sheets of graph paper per student
1 - 150 W flood lamp if experiment is to be done indoors

*<u>Note:</u>*
*Some modifications that might be tried are:*
*-Glauber's salt [50% with water]*
*-gypsum [$CaSO_{4(s)}$] [plaster of Paris]*
*1 - brick painted black [384 $cm^3$]*
*1 - styrofoam covered milk carton*
*1 - electric oven*

*This experiment is best done indoors with a 150 W flood lamp or sunlamp unless several hou of bright sunshine will be available. There are many other materials that could also be testec Glauber's Salt either pure or mixed with other chemicals [e.g., sodium chloride] could be tried. T avoid supersaturation, try stirring the molten material with a wire that comes out the top of the mil carton. Zeolite is another substance currently being researched. The details are sketchy. Apparently heat energy from solar radiation is used to dry wet zeolite and when water is later added large quantities of heat are released.*

*This experiment could also be extended to deal with shapes and different arrangements of heat storage materials [e.g., trays of materials] and more detailed discussions of thermal conductance of materials. Calorimetric determinations of specific or volumetric heat capacities of possible thermal heat storage materials could be done as a related experiment.*

**Sample Results - Postlab Exercise:**

2. Bar graph results for 2 h period:
   water, concrete, stones, sand, wood
   655 591 401 317 226
3. Bar graph results for the first 20 min:
   concrete, water, stones, sand, wood
   190, 172, 155, 134, 102
4. The variables controlled in the lab were:
   - total volume of materials
   - color and type of container
   - initial and ambient temperatures
   - heat transfer container
   - time frame

*Note:*
***Computer programs will be available for Apple II microcomputers from the authors in the near future. The programs will, for example, plot graphs of the results and calculate the area under the curve very easily.***

**Conclusions:**

1-4 *See sample data above* [*or, better yet, your data*] *and combine this with cost and convenience in your area.*

5. (The rankings, particularly cost and convenience, will be subject to local conditions, other materials tested and some subjective opinion.)
   best: water and/or concrete [***If Glauber's salt is stirred it turns out best.***]
   worst: wood
6. The assumption is made that each characteristic is of equal value. This assumption will not usually be true. A weighted average ranking would be better.
7. The five materials ranked from highest to lowest volumetric heat capacity are: water, concrete, stones, sand and wood. This order should agree with the heat lost rankings over a long period (2 (2 h).
8. Thermal conductance (the ability to store and release heat quickly) would also be important.
9. This problem could be eliminated by transferring heat from the storage by mechanical means (e.g., pumps and fans). (A correct passive solar energy design would be an open design to allow for thermosiphoning within the home.)

***Note:***
***This would be a good point for a quiz on solar heat storage.***

**Pages 44-58: Active Collection and Storage of Solar Energy**

*This section could be done very quickly or in more detail. The information presented is particularly useful to students doing projects on active* [*or passive*] *collector panels.*

*Emphasize that the same principles of collection, heat transfer and heat storage apply to passive systems and active systems* [*i.e., the house is the collector for passive systems*].

**Page 52: Overview of Active Collection**

1. An active collector uses fans and pumps to circulate the heat, whereas, a passive collector depends on a natural thermosiphon effect.
2. The economic cost factors to be considered when comparing heating with fossil fuels and heating with active collectors are amortized cost of the collector system, present and projected cost of fossil fuels and maintenance costs of both systems.

*"Cost" might also be interpretted to mean environmental or future costs* [*e.g., pollution and the lack of petrochemical* [*e.g., plastics*] *feed stock for future generations*].

3. (See Figure 47, Page 46.)

4. Solar radiation, transmitted by the glazing of an active collector, is absorbed and converted to heat by the dark collector plate. Heat energy is transferred from the collector plate to the collector fluid by conduction and radiation. The collector fluid is circulated through the storage tank or the house heating system.

5. The efficiency of an active solar collector is determined by the orientation of the collector, the glazing, the collector surface and inter-glazing medium, the heat losses and the collector fluid.
6. Graph A represents single galzing which is more efficient at low temperature differences because it has a higher transmission coefficient. Graph B represents double glazing and it is more efficient at higher temperature differences because of the reduced heat loss from the double glazing.
[*Compare RSI values given on Data Sheet.*]
7. 44.4%
8. 55°, 25° [(latitude + 15°) and (latitude -15°), respectively]

**Pages 53-58: Solar Heat Storage in Active Systems**

*Calculations on the size of heat storage tanks require the following estimates:*

1. *average solar radiation data*
2. *area and efficiency of collectors*
3. *home space heating requirements to be fulfilled [e.g., 50% of January heating requirements for 2 consecutive sunless days]*
4. *heat losses throughout the system*

*It is recommended in practical solar energy books that the storage capacity be designed to obtain 400* kJ/°C *for every square metre of collector area.*

$$\textit{Total storage required} = \frac{\textit{Collector Area} \times 400\ \mathrm{kJ/(°C.m^2)}}{\textit{Heat Capacity}}$$

**Page 56: Thermal Heat Storage in Active Systems**

1. 124 $m^3$
2. 87 $m^3$
3. 3.3 GJ
4. 10.4 GJ
5. 2.39 $m^3$
6. 7.75 GJ ($78 - electrical; $16 - gas)

**Pages 59-63: Overview of Active and Passive Systems**

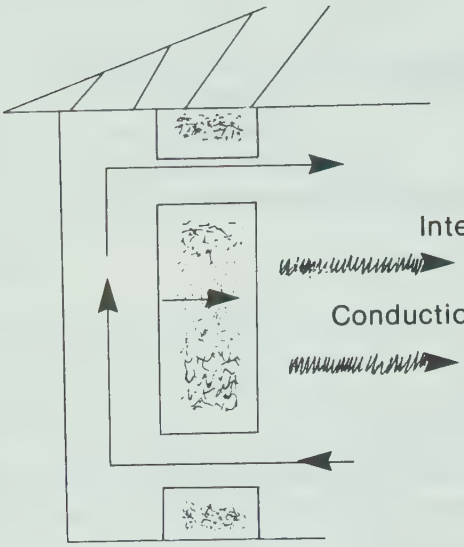
1. South and east facing windows increase entry and collection of solar energy when needed. (West facing windows produce over-heating in the summer months.)
2. Entry and collection of solar energy are controlled by deciduous trees on the south side. Coniferous trees and earth berms on the north and northwest provide shelter from winds (and summer-evening sun).
3. Extra window area increases entry and collection of solar energy during the heating season. Materials inside the greenhouse act as heat storage materials. Plants also collect and store the solar energy - as chemical energy.
4. Insulation increases the efficiency of solar energy collected by decreasing heat losses by a storage system and the house. Insulation also keeps the house cooler in the summer.
5. A vapor barrier prevents infiltration of cold air in the winter and warm air in the summer. A continuous vapor barrier is receiving more and more attention in the building trade.
6. Insulated window shutters allow collection when needed and prevent heat losses during cold nights. They can also be used effectively in reverse during the summer.
7. Thermal mass absorbs solar energy collected to prevent overheating and releases heat when the house starts to cool off at night.

*Note the semi-color divisions as assistance in answering. An [not the] answer is provided below.*

8.

| passive | | active | |
|---|---|---|---|
| direct | indirect | low cost | high cost |
| window, sunspace, | mass, thermosiphon, | flatplate, focusing | tracking, evacuated |

9.




10. Average solar energy = $\frac{\text{mean daily}}{\text{solar radiation}}$ x 3.0 $m^2$ x 31 d

11. A good heat storage material should have a high specific, volumetric or latent heat capacity as well as a good heat conductivity.
12. Water as a heat storage material compared to rock is more compact, has a higher thermal conductivity and can **operate more efficiently at lower temperatures.** However, water can promote corrosion and leaks can be a serious problem.
13. Glauber's salt is a very compact heat storage medium that can operate at a relatively low temperature. Glauber's salt does not require an ever increasing temperature of the collector fluid to keep storing heat energy.
    Corrosion, supersaturation and uneven crystallization are the main disadvantages.
14. Passive solar heat design is relatively inexpensive, reliable and forms an integral part of a house. Active systems are generally expensive, can be unreliable and involve maintainence problems. Active systems will probably only be economically viable if governments provide tax allowances and fossil fuel cost rise to much high levels.
15. 1.5 GJ ($15 - electrical, $3 - gas)
16. 0.28 GJ ($2.8 - electrical, 56¢ - gas)
17. 1.1 MJ ($11 - electrical, $2.2 - gas)
18. Forced-air heat transport is fast and does not pose any corrision or leak problems.
19. **Heat losses are greater as the temperature difference increases. High temperature operation of a** heat storage medium requires more insulation and increasingly higher temperatures of the collecting fluid (which decreases the efficiency of the collector; see the graph on Page 49).
20. If the temperature of the storage medium is too close to the expected room temperature the rate of heating becomes very slow.
21. 6.7 MJ/($m^2$.d) 22. 1.7 x $10^2$ $m^2$
23. This collector area would be very impractical since it is approximately 50% larger than the floor area of the house. It would also be prohibitively expensive. (Some such experimental, collector systems have been constructed as free-standing units.)
24. 29% 25. $31 26. 8.0 $m^3$

27. and 28. *Requires local data. Depending on the level of the students they may require some direction. Emphasize the importance of units in helping to set up the calculations. The purpose of these two questions is not to obtain* 100% *reliable figures, but, instead to illustrate that solar energy can provide significant savings on a yearly basis.*
29. In planning an actual system the amortized cost, the cost of competing energy sources and possible tax benefits need to be considered.
30. There seems to be a general attitude that highly sophisticated technology will solve any problems we have. New technology and manufacturing do have desirable economic benefits in creating jobs and profits.

**Page 69: Concentrating Collectors**

1. Cooking, generation of electricity, distillation of sea water and industrial applications all require reasonable high temperatures for efficient operations.
2. *Reflective shutters and reflective venetian blinds are possibilities here.*
3. *Assume a 1.00 $m^2$ collector for Edition 1.*

$$\text{heat produced from solar energy} = \text{heat gained by water}$$
$$(600\ \text{J/s} \times 0.80 \times 0.95 \times 0.75)\ T = mc\,\Delta t$$
$$T = 980\ \text{s or } 16\ \text{min}$$

**Page 72: Solar Cells**

1. (See Page 71.)
2. *Various levels of answers could be given in answer to this question. A very simple answer might be as below.*
   Energy from the solar radiation allows electrons to flow (i.e., an electrical current) from one layer of the cell to the other layer.
3. (See Page 71.) 4. 0.40 kW
5. *Possible methods for storing electrical energy* **involve converting it into another form.** Some examples are batteries, hydrogen and oxygen gas, gravitational potential energy of water and compressed gases.

It should be noted that although solar cells only occupy a position in the appendices of the Solar Energy book, a similar book in ten years time might have to change this **emphasis** drastically. Solar Energy is a product of its time and place — as all books are.

**Introduction**

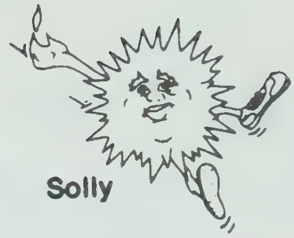
Note: These items are samples only. Please revise these items to suit your own needs.

In the left margin beside each item is a possible best answer, the number of the unit objective that it was designed to test and the page number where you may find the background theory for the item.

Below is a table which matches **question number,** unit objective and page for background theory.

**Solly**

| Objective | Question # | Background Theory Page # |
|---|---|---|
| 1 | 27 | 3 |
| 2 | 2, 51, 55 | 1 |
| 3 | 3, 5 | 5-6 |
| 4 | 31, 40 | 3 |
| 5 | 20 | 6 |
| 6 | 35, 47 | 7 |
| 7 | 26, 38 | 8 |
| 8 | 32 | 10, 11 |
| 9 | 30, 33, 36 | 8, 11, 10 |
| 10 | 4 | 12 |
| 11 | 1, 34 | 13, 14 |
| 12 | | |
| 13 | 11, 29, 42, 43 | 19 |
| 14 | 28, 50 | 18 |
| 15 | 6, 7, 10, 15, 52 | 21, 27 |
| 16 | 12 | 23 |
| 17 | 39, 45, 48 | 28 |
| 18 | 41 | 30 |
| 19 | 8 | 30 |
| 20 | | |
| 21 | 24, 54 | 25 |
| 22 | 9 | 33 |
| 23 | 17, 37 | 39, 40 |
| 24 | 13, 19, 25, 49, 56 | 37, 39 |
| 25 | | |
| 26 | | |
| 27 | | |
| 28 | 21, 22, 23, 44, 53 | 46, 48 |
| 29 | | |
| 30 | 14 | 20 |
| 31 | 18 | 53 |
| 32 | | |
| 33 | 16 | 69 |
| — | 46, 57 | — |




| # |
|---|
| Answer |
| Objective |
| Page |

1. The rotation of a vane-type radiometer exposed to sunlight is due to the greater force of

A A. air molecules striking the black side compared to the white side of the vanes
11 B. light striking the black side compared to the white side
13 C. air molecules striking the white side compared to the black side
D. light striking the white side compared to the black side

2. The energy source listed below which is NOT related to radiant solar energy is
C A. wind B. hydro
2 C. tides D. oil
1

3. The source of solar energy can best be described as
A A. nuclear energy B. chemical energy
3 C. kinetic energy D. heat energy
5

4. **A situation in which conduction plays a major role is**
A. heat escapes from a house in winter through the walls
A B. a radiometer turns in bright sunlight
10 C. a clear night is often cooler than a cloudy night
12 D. the air is generally warmer at the ceiling than at the floor

5. The illumination of the sun is
A. directly proportional to the square of the distance from the sun
C B. inversely proportional to the distance from the sun
3 C. inversely proportional to the square of the distance from the sun
6 D. directly proportional to the distance from the sun

6. The orientations for windows of a passive solar home arranged from best winter heating to worst are:

B A. S, W, E, N
15 B. S, E, W, N
21 C. N, W, E, S
D. E, W, S, N

7. Overheating during the summer can be significantly prevented or reduced by all of the following EXCEPT

C A. roof overhang
15 B. movable shutters
21 C. double glazing
D. clerestory vents

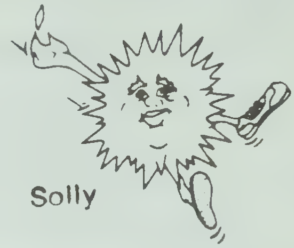
8. Active or passive solar energy storage for space heating normally uses
A. a large thermal mass
A B. south-facing orientation of the house
19 C. large windows
30 D. proper landscaping

| # |
|---|
| Answer |
| Objective |
| Page |

9.
D
22
33

Which one of the following features of a solar home is NOT used to maximize the entry of the solar energy during winter?

A. clerestory
B. number and size of windows
C. attached greenhouse
D. Trombe wall

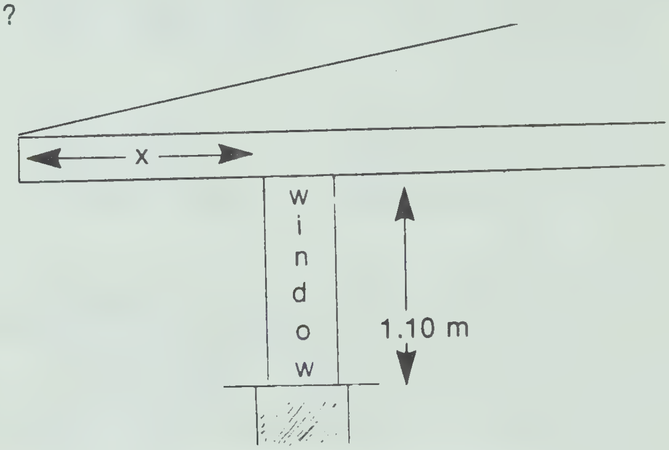

Solly

Use the following diagram to answer the next question.

10.
B
15
27

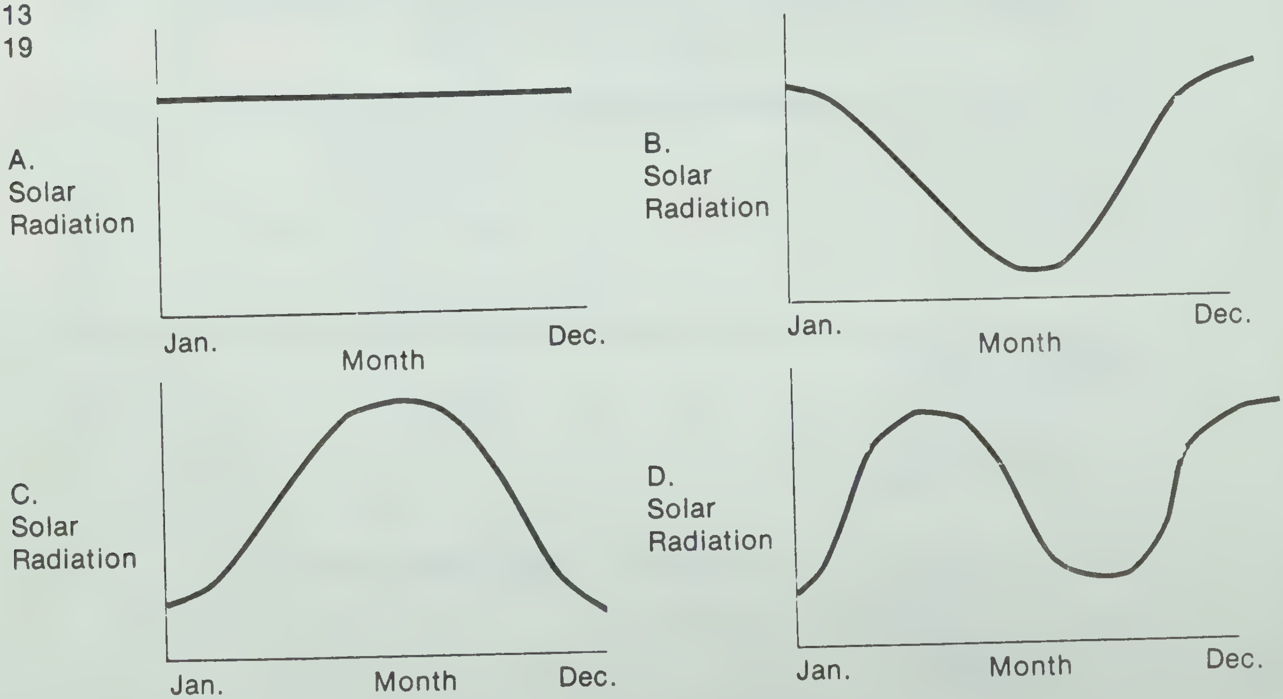
What overhang (x) is required to completely shade the window on June 21st when the solar altitude at noon is 60°?

A. 0.36 m
B. 0.64 m
C. 1.6 m
D. 1.9 m




11.
C
13
19

Which of the following graphs is a plot of Mean Daily Solar Radiation versus Month on a horizontal surface?




12.
C
16
23

Which of the following would be the least suitable for retrofitting?

A. solar greenhouse
B. reflective shutters
C. clerestory
D. window box collector

13. A 5.00 m by 2.50 m by 0.40 m concrete Trombe wall was heated to 30°C by solar radiation during the day. As it cools to a final temperature of 19°C during the night, how much heat does it release to the inside of the house?

D
24
37

A. 13 MJ
B. 44 MJ
C. 16 MJ
D. $1.2 \times 10^2$ MJ

14. Which of the following is NOT a true statement about passive and active solar systems?

D
30
20

A. Passive systems are more natural than active systems.
B. Passive systems are less mechanical than active systems.
C. Passive systems are less costly than active systems.
D. Passive systems collect more solar energy per square metre than active systems.

15. The floor area of a passive solar home is usually recommended to be

B
15
21

A. about the same as the total window area
B. 3 to 10 times larger than the total south-facing window area
C. 3 to 10 times larger than the total window area
D. 6 to 8 times larger than the total south-facing window area

16. A major disadvantage of concentrating solar collectors is that they

D
33
69

A. overheat
B. reflect most of the light energy incident upon them
C. can use only diffuse solar radiation
D. can use only direct solar radiation

17. Which of the following would NOT be a typical example of a thermal mass storage system?

A
23
39

A. eutectic salt storage
B. culvert storage
C. Trombe wall
D. concrete floor

18. An important advantage of passive solar heating systems over active systems is

A
31
53

A. all of the below
B. they are cheaper to maintain
C. they are economically viable for a wide range of fossil fuel costs
D. they are cheaper to build

19. What volume of Glauber's salt is required to store 25.0 MJ of heat?

A
24
39

A. 0.0708 $m^3$
B. 0.103 $m^3$
C. 14.1 $m^3$
D. 17.1 $m^3$

20. The three main regions of the solar spectrum listed in order from smallest to largest fraction present in solar radiation are

A
5
6

A. UV, visible, IR
B. IR, visible, UV
C. UV, IR, visible
D. visible, UV, IR

21. The collector panel or plate in a water collector is usually a metal plate because of its

B
28
46

A. low cost
B. good thermal conductivity
C. ease of installation
D. high heat capacity

| # |
|---|
| Answer |
| Objective |
| Page |

22. The surface of a collector panel and the tubing are usually painted black to
A. maximize the absorption of solar energy
A b. increase the thermal conductivity
28 C. protect the surfaces from corrosion
46 D. blend in better with the surroundings


23. The major purpose of the glazing (glass or plastic) is to
A. reduce heat loss from the collector
A B. protect the collector surface
28 C. increase the entry of solar radiation
48 D. prevent overheating

24. A thermosyphon in a passive collector requires
A. **the inlet and outlet be at the same level on the collector**
D B. a storage tank below the collector panel
21 C. the inlet above the outlet on the collector
25 D. a storage tank above the collector panel

25. What volume of water is necessary to store 419 MJ of heat while rising in temperature
C from 22.0°C to 42.0°C?
24 A. 0.200 $m^3$ C. 5.00 $m^3$
37 B. 2.38 $m^3$ D. 21.0 $m^3$

26. Solar energy absorbed by the atmosphere
A. includes all of the below
A B. results in heating of the atmosphere
7 C. is reradiated by the atmosphere
8 D. is usually less than the amount reflected by the atmosphere

27. Which of the following statements about the present use of solar energy is FALSE?
A. an insignificant amount of solar energy is used for practical purposes
A B. a significant amount of direct solar energy is used for heating homes
1 C. a massive amount of solar energy is used as stored energy
3 D. we do not make as much use of solar energy as would be practically possible

28. The mean daily solar radiation for the year on a horizontal surface at a certain location is 12.0 MJ/($m^2$.d). The amount of solar energy that would fall each year on a 10 $m^2$
D horizontal surface is
14 A. 0.12 GJ/a C. 4.4 GJ/a
18 B. 0.33 GJ/a D. 44 GJ/a

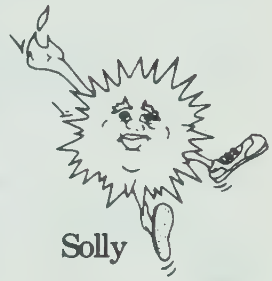
29. The maximum solar power per square metre of horizontal surface occurs on
D A. Dec. 21 B. Sept. 21
13 C. March 21 D. June 21 ***Assume north of Tropic of Cancer.***
19

30. Which of the following has the least effect on the seasonal change in the amount of solar energy reaching the Earth's surface?
A. latitude
B B. Earth-sun distance
9 C. weather conditions
8 D. dust particles

| # |
|---|
| Answer |
| Objective |
| Page |

31. Which of the following is NOT an advantage attributed to solar energy?
A. solar energy is renewable
D B. solar energy is non-polluting
4 C. the amount of total solar energy available is large
3 D. solar energy is a concentrated form of energy

32. If the solar altitude at solar noon on June 21 is 60.0° at 53°N latitude, the solar
C altitude at the same latitude at noon on March 21 will be
8 A. 13.0° B. 30.0°
10, 11 C. 36.5° D. 83.5°




33. A decrease in solar altitude results in a decrease in
A. absorption and reflection by the atmosphere
B B. the radiation per unit horizontal area
9 C. the pathlength
D. none of the above

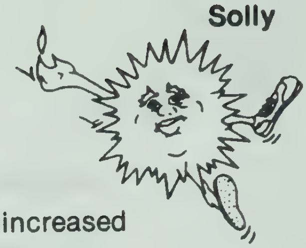
34. A strobe with 10 slits was rotated at the fastest speed necessary to "stop" the motion of the four radiometer vanes. If 10 rotations of the strobe took 4.5 s, the frequency of
B rotation of the radiometer vanes was
11 A. 2.2 Hz C. 8.9 Hz
14 B. 5.6 Hz D. 22 Hz

35. Using 22.6 MJ/($m^2$.d) as the monthly mean daily solar radiation for a horizontal
D surface, the average solar power per unit area during a 15 h day is
6 A. 2.4 kW/$m^2$ C. 1.2 kW/$m^2$
7 B. 1.5 kW/$m^2$ D. 0.42 kW/$m^2$

36. Which one of the following factors does NOT affect the pathlength of solar radiation?
A. solar altitude
C B. solar azimuth
9 C. composition of the atmosphere
10 D. season of the year

37. Latent heat storage is more attractive for solar energy applications than thermal heat storage because latent heat storage
B A. is generally less expensive
23 B. can store larger amounts of heat per unit volume
40 C. is simple in principle and practise
D. eliminates problems of corrosion

38. The fact that the average temperature on Earth is constant indicates that
A. the total absorption of solar radiation equals the total reflected
B B. all of the incident solar radiation is either reflected or radiated back into outer
7 space
8 C. the amount of solar radiation absorbed is negligible
D. the total incident solar radiation is either absorbed, reflected or transmitted by the atmosphere



| # |
|---|
| Answer |
| Objective |
| Page |

39. Compared to typical houses a low energy home would have increased
   A. air infiltration
B  B. insulation
17  C. window area
28  D. floor area

40. The FALSE statement regarding solar energy is that
   A. solar energy is renewable and available in large amounts
D  B. solar energy can be collected inexpensively
4  C. many uses of solar energy require long term planning
3  D. solar energy requires high technology

41. Which of the following statements concerning the greenhouse effect is FALSE?
   A. window glass is as transparent to long wavelength IR radiation as it is short IR
B  radiation
18  B. absorbed IR-radiation is re-emitted at a shorter wavelength
30  C. glass reduces heat loss by radiation and convection
   D. increasing the thermal mass behind the window increases the greenhouse effect

*Note: See more multiple choice items on the next page.*

Show complete solutions for the following problems with units cancelled and answers properly rounded off.

1. How much heat can be stored in a rectangular tank 7.50 m x 7.50 m x 2.20 m high filled with rock with a 30% void when the temperature rises from 25.0° to 45.0°C?

**Answer 3.3 GJ**

2. Calculate the money saved on the monthly fuel bill due to solar collection for January, using the following data.

   Mean solar radiation on collector = 13.3 MJ/($m^2$.d)
   Efficiency of collector = 50%
   Dimensions of collector = 5.00 m by 10.00 m
   Cost of fuel = 0.30c/MJ
   Days in January = 31

Answer $30

42. The maximum solar power per square metre of vertical surface occurs in your location on

A
13 A. March 21 C. September 21
19 B. June 21 D. December 21

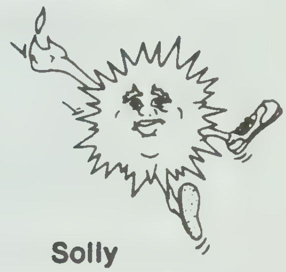
43. The most important variable affecting the amount of solar radiation collected is

A A. tilt of the collector
13 B. pathlength of the solar radiation through the atmosphere
19 C. solar altitude
D. solar azimuth

44. The efficiency of an active solar collector is affected by

*Note: There are too many A & B answers.*

A A. all of the below
28 B. type of glazing
46 C. the amount of insulation
D. the ambient temperature



Solly

45. The average house today loses most of its heat by

B
17 A. radiation C. conduction
28 B. convection

46. The highest energy photon listed below is

B A. IR
— B. UV
— C. visible
D none of the above, they are all the same energy

47. On a bright summer day the perpendicular solar power per square metre at noon would be approximately

B
6 A. 500 W/m$^2$ C. 2000 W/m$^2$
7 B. 1000 W/m$^2$ D. 4000 W/m$^2$

48. For a low energy passive solar home, the south-facing window area should be approximately what percentage of the house floor area? (Answer for your location.)

B
17 A. 1% C. 30%
28 B. 10% D. 50%

49. What volume of concrete is required to store 250 MJ of heat (about one thirtieth of an average days requirement for heating an Edmonton energy inefficient home in January)? Assume a
B maximum temperature change of 15°C for the concrete.
24
37 A. 5.5 m$^3$ C. 13 m$^3$
B. 7.9 m$^3$ D. 18 m$^3$

50. The space heating requirement for an average high energy home in Edmonton in March is 560 MJ/d. The percentage of space heat that can be provided by 11.0 m$^2$ of vertical, south-facing,
D double glazed windows in March in Edmonton is
14
18 A. 5.0% C. 16%
**B. 9.8%** **D. 28%**

51. Which of the following is not a renewable form of energy for large scale use?

A A. chemical C. wind
2 B. solar D. hydroelectric
1

52. The depth of shadow cast by a 0.60 m eave at solar noon on March 21 in Edmonton is

A
15 A. 0.45 m C. 0.80 m
27 B. 0.60 m D. 1.3 m

53. The collector plate in a flat-plate collector is usually made of metal because of the metal's

B A. low cost
28 B. high thermal conductivity
46 C. high heat capacity
D. ease of installation

Solly

54. A thermosiphon in a passive system requires

A A. all of the below
21 B. the outlet above the inlet on the collector
25 C. the storage "tank" above the collector panel
D. the inlet and outlet on opposite ends of the collector

55. All the energy that man makes use of can ultimately be traced back to a source of

D A. magnetic potential energy
2 B. gravitational potential energy
1 C. electric potential energy
D. nuclear potential energy

56. What mass of Glauber's salt is required to store 250 MJ of heat (about 1/30 of an average days requirement for heating a high energy Edmonton home in January)?

A
24 A. 1.03 Mg
39 B. 60.5 Mg
C. 96.8 Mg
D. 103 Mg

57. Which of the following statements is FALSE?

C A. If the R-value is 4.0, the thermal conductivity is 0.25.
— B. If the transmission coefficient for single glazing is 0.80, it is 0.64 for double glazing.
— C. If the solar constant is 600 $W/m^2$, it is also 22.0 $MJ/(m^2.d)$.
D. If the frequency is $2.0 \times 10^{14}$ Hz, the photon energy is $1.3 \times 10^{-19}$J.

58. A solar energy pioneer wishes to build a Trombe wall behind a 2.00 m by 5.00 m vertical, south-facing, double glazed window. She wants to store 40% of an average two days supply of solar energy through the window in January. If the concrete wall is made the same height and width as the window, what must be the thickness of the wall to keep the temperature change within 15°C? (Hint: Calculate what you can until you get the answer.) (Assume no shading of the window by the eave.)

Answer 0.21 m
(Edmonton)

59. a) Calculate the heat lost conduction through a double galzed (0.6 cm air) 3.00 m by 5.00 m window over an average two day period in January in your location. (The average indoor temperature can be assumed to be 20°C. The average outdoor temperature must be obtained from your data sheet or teacher.)

Answer: $h_L = \frac{1}{0.30\ \frac{m^2 \cdot °C}{W}} \times 34.7°C \times 3.00\ m \times 5.00\ m \times 2.00\ d \times \frac{3600\ s}{h} \times \frac{24.0\ h}{d} = 0.30\ GJ$
(Edmonton)

b) Calculate the solar gains for the above window.

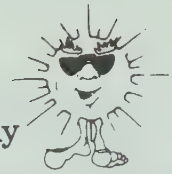
Answer: $E_S = 10.2\ \frac{MJ}{m^2 . d} \times 3.00\ m \times 5.00\ m \times 2.00 d \times 0.81 = 0.25\ GJ$
(Edmonton)

c) What is the percentate efficiency of the window as a solar collector?
($\frac{\text{Gains-Loses}}{\text{Gains}}$ x 100 = )

d) What can be done to increase the efficiency?

-thermal curtains
-thermal shutters
-triple glazing
-bead window
-blinds
-reflector
-insulating glazing


Solly



Solly

Show complete solutions for the following problems with units cancelled and answers properly rounded off.

60. A 5.00 m by 2.50 m by 0.40 m concrete Trombe wall was heated to 30°C by solar radiation during the day. As it cools to a final temperature of 19°C during the night, how much heat does it release to the inside of the house?

Answer 0.12 GJ

61. Calculate the money saved on the monthly fuel bill due to solar collection for January, using the following data for an unshaded double glazed south-facing window.

Mean daily solar radiation on a vertical south-facing surface = 10.2 MJ/($m^2$.d)
Dimensions of window - 4.00 m by 2.00 m
Cost of fuel - 0.50c/MJ
Days in January - 31

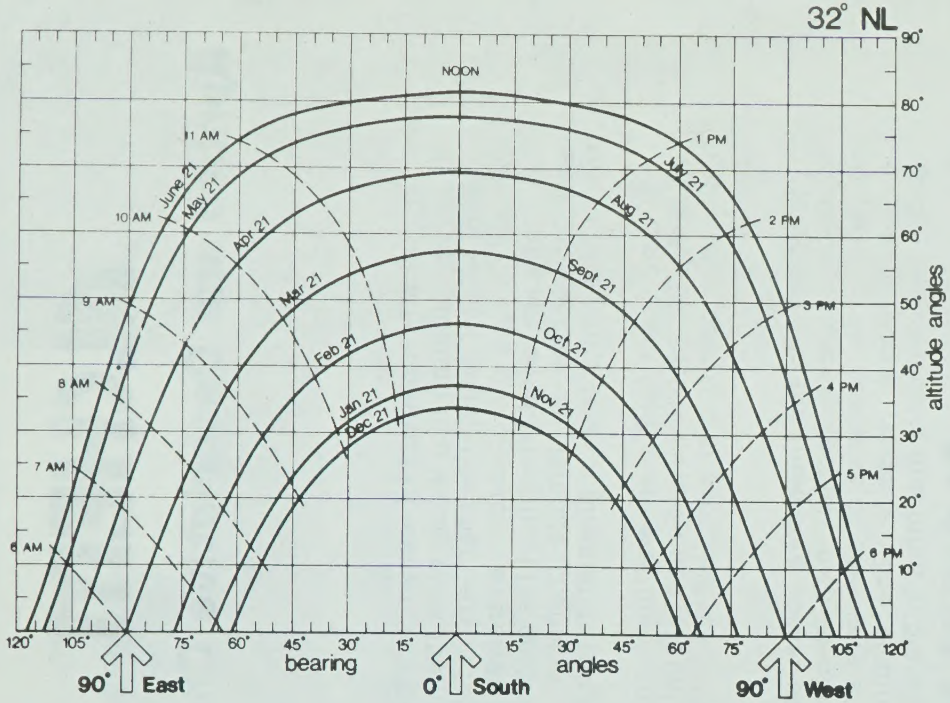
Answer $10

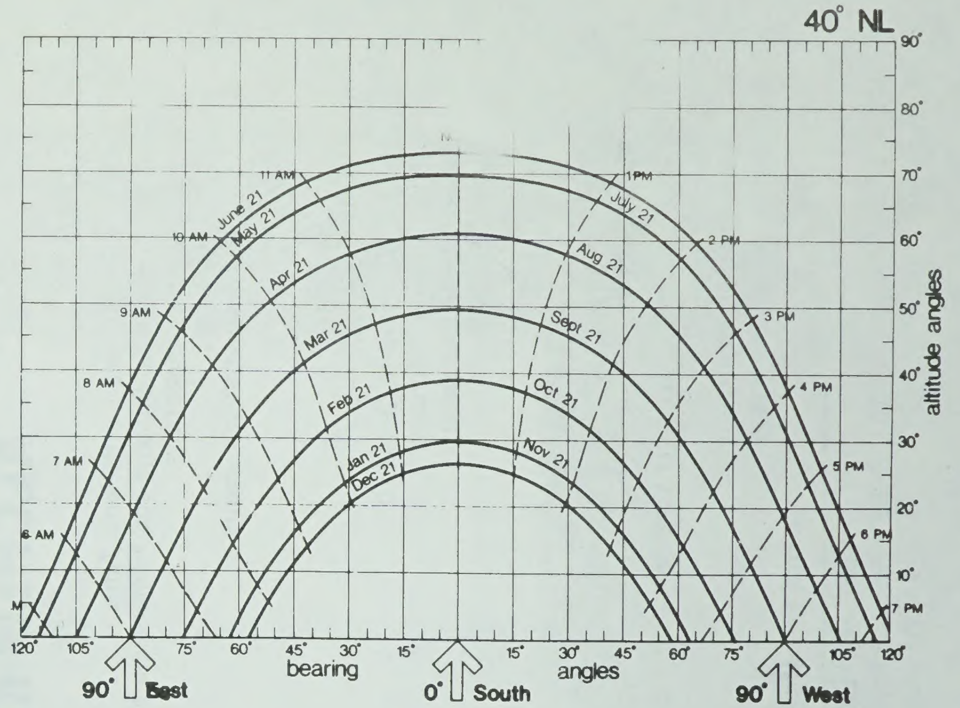
62. Define solar altitude and solar azimuth.

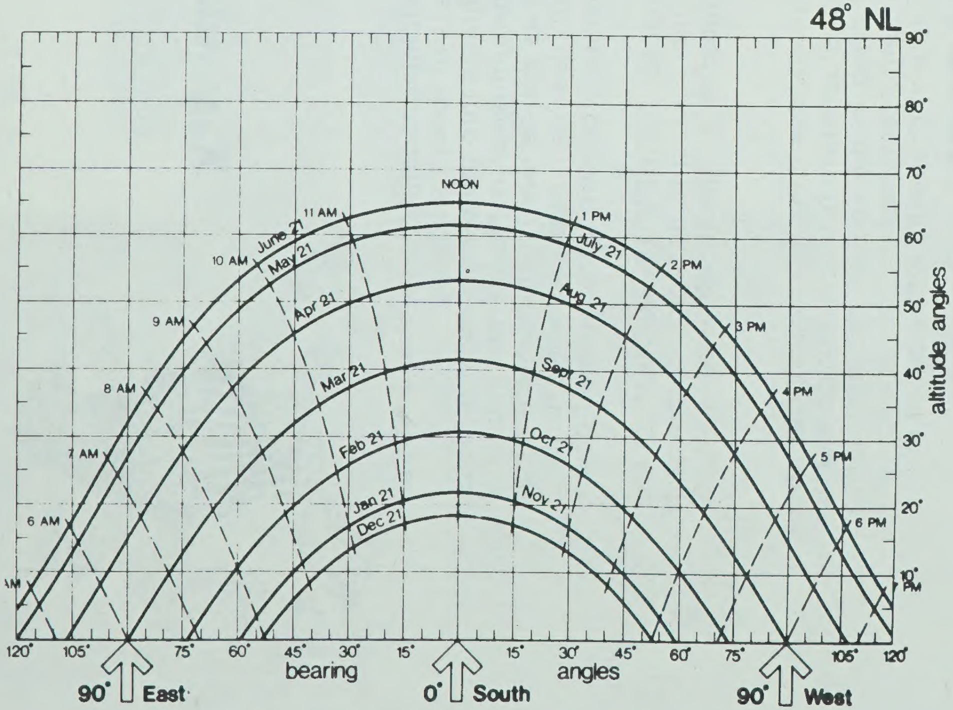
Answer-See Page 9

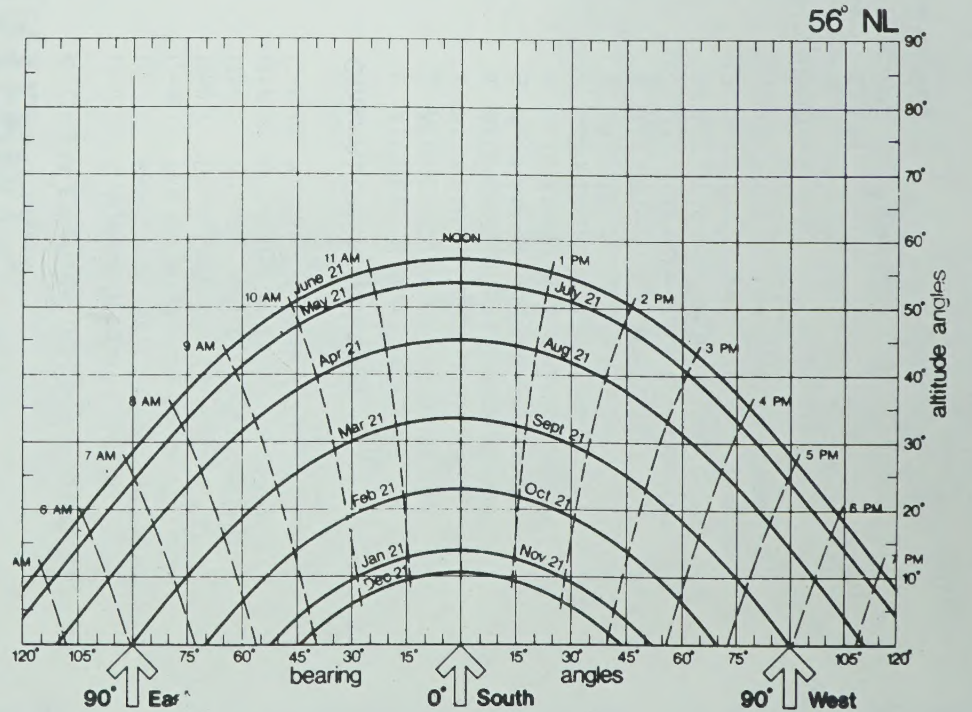
63. List 5 variables which affect the amount of solar energy stored by a thermal mass.

Answer-See Page 30


32° NL
NOON
June 21
May 21
Apr 21
Mar 21
Feb 21
Jan 21
Dec 21
July 21
Aug 21
Sept 21
Oct 21
Nov 21
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
altitude angles
bearing angles
90° East
0° South
90° West


40° NL
June 21
May 21
Apr 21
Mar 21
Feb 21
Jan 21
Dec 21
July 21
Aug 21
Sept 21
Oct 21
Nov 21
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
altitude angles
bearing angles
90° East
0° South
90° West


48° NL
NOON
June 21
May 21
Apr 21
Mar 21
Feb 21
Jan 21
Dec 21
July 21
Aug 21
Sept 21
Oct 21
Nov 21
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
altitude angles
bearing angles
90° East
0° South
90° West


56° NL
NOON
June 21
May 21
Apr 21
Mar 21
Feb 21
Jan 21
Dec 21
July 21
Aug 21
Sept 21
Oct 21
Nov 21
6 AM
7 AM
8 AM
9 AM
10 AM
11 AM
1 PM
2 PM
3 PM
4 PM
5 PM
6 PM
7 PM
altitude angles
bearing angles
90° East
0° South
90° West